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LATTICE GIRDER OVERHEAD CROSSING—CHICAGO, SANTA FÉ & CALIFORNIA RAILWAY.

By W. H. Breithaupt, Member of the Engineers' Club of Kansas City.

[Read June 18, 1888.]

A considerable impediment to fast travel on railways and a constant source of danger is their crossing each other on the same level. In the West, where there are more new and more cheaply built railways, grade crossings are all but universal. Its avoidance of grade crossings with other railways is a prominent feature of the Chicago, Santa Fé & California Railway. There are between Kansas City and Chicago, by this line 458 miles, 16 over or under crossings. In some cases the general grade of the new road could be brought to sufficient elevation to give the required headway over the road to be crossed without necessitating much extra embankment. Generally, however, such extra embankment was required.

The longest of the crossing viaducts spoken of is that over the Missouri Pacific and Chicago & Alton tracks at Rock Creek, four miles east of Kansas City. While not a work of particular magnitude, as compared to other structures on the line, the conditions involved made the bridging of this crossing a problem of considerable interest. There will be, when all contemplated side tracks are in, six Missouri Pacific and two Chicago & Alton tracks crossing the centre line of the C., S. F. & C. track at angles of 36° 36′ and 36° 38′.

The lower tracks are so spaced that while maintaining the required lateral clearance of seven feet each side of centre line of track, enough points of support can be obtained to break the structure into four spans. These spans are of through, single intersection, Warren riveted girders of uniform height, and are of the following lengths, beginning at the west end: Span one, 82 feet; span two, 53 feet 4⅝ inches; span three, 68 feet 8⅝ inches; and span four, 64 feet 1¼ inches, making in all 268 feet 2⅝ inches from end to end of iron work. The extreme ends of the bridge rest on masonry abutments. The intermediate supports are: No. 1, a bent braced both longitudinally and transversely, forming in effect a pier; Nos. 2 and 3, bents formed of two posts and a cross girder. These posts and the entire superstructure are built of plates and angles, partly

because better sections could thus be obtained, and partly on account of the higher price asked for channel and I beam sections. All vertical posts rest in cast-iron pedestals, and these on pedestal piers.

Fig. 1 gives a general elevation of the structure, and Fig. 2 a plan view showing lower tracks.

The specifications for superstructure do not differ much from other good specifications for similar structures.

They require in general that spans up to 75 feet in length are to be of plate girders. from 75 feet to 100 feet, or 110 feet of single intersection, Warren riveted girders, and beyond that length of pin connected Pratt trusses.

Where iron floor is used it is to consist of floor beams and four lines of stringers. two inner, each placed directly under the rail figured for the full live load. and two outer safety stringers of half the strength of main stringers, to act in case of derailment only.

The assumed live load consists of two 86-ton consolidation engines each of 52 feet wheel base, followed by a train weighing 3,000 pounds per foot.

The dead weight of the track rails and guard rails is taken at 200 pounds per foot, and the cross-ties 4 pounds per foot board measure.

All strains are to be determined by that position of the live load which causes the greatest strains in any member or section. The calculated strains due to the above loading are increased as follows, as an allowance for the momentum of the live load:

For girders of length of 30 feet or less 25 per cent.

For girders of length of 30 to 50 feet 20 per cent.

For girders of length of 50 to 75 feet 15 per cent.

For girders of length of 75 to 90 feet 10 per cent.

Under "girders of length of 30 feet or less" come all floor beams and stringers.

Wind strains shall be calculated at 40 pounds per square foot of exposed surface of one girder in case of plate girders, and of 80 pounds per square foot in case of lattice girders as a dead load, and a moving load equal to 30 pounds per square foot of the exposed surface of a train of coaches extending across the bridge, the surface of the coaches being supposed to extend from a line 4 feet above the rail to a line 15 feet above the rail.

Chord members of girders shall not be subjected to strains greater than 7,000 pounds per square inch in compression, nor greater than 8,000 pounds per square inch in tension. Shear in webs of plate girders shall not exceed 4,000 pounds to the square inch, and the webs only shall be considered as resisting shear.

Strains in compression members in lattice girders must not exceed values obtained by the following formula for the strength of columns:

$$S = \frac{7500}{1 + \frac{L^2}{40000\ R^2}}$$

S = Strain per square inch.
L = Length in inches.
R = Least radius of gyration.

Good riveting is particularly strongly specified. Rivets regularly are taken at 6,000 pounds in shear and 12,000 pounds in bearing. The number of rivets in field connections of floor beams and stringers, as obtained from these values, is to be increased 25 per cent. No steel rivets are to

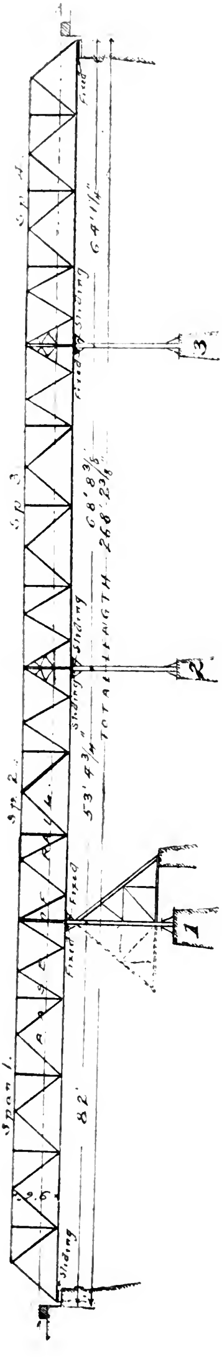

Span 1.
Sp. 2
Sp. 3
Sp. 4
82'
53' 4 3/4"
68' 8 3/8"
64' 1 1/4"
TOTAL LENGTH 268' 2 3/8"
Sliding
Fixed
1
2
3

Fig. 1.

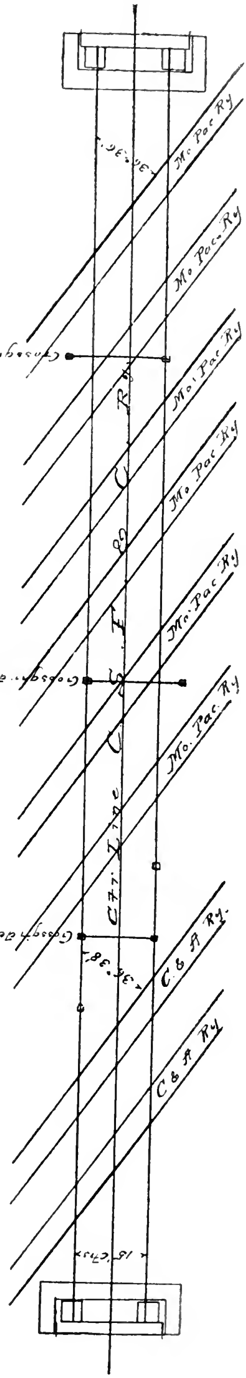

Mo. Pac. Ry
Mo. Pac. Ry
Mo. Pac. Ry
Mo. Pac. Ry
Mo. Pac. Ry
Mo. Pac. Ry
Mo. Pac. Ry
C & A Ry.
C & A Ry
C. & E. I. R.R.
C. & E. I. Line
Cross girder
15' c. to c.

Fig. 2.

be used in field riveting. Expansion rollers are not required for girders less than 70 feet in length, but expansion and contraction must be provided for by leaving one end of the bridge free to slide on planed surface of the bed plate.

The webs of plate girders must be spliced at all joints by two plates, one on each side.

Abutting joints, whether in tension or compression, must be fully spliced; but abutting joints in compression must nevertheless be planed true and make a full bearing across the width of the plates.

Gusset plates on inside of through girders at floor beams or lateral strut connections must not project above the top of the floor system so as to be liable to be struck by the journal box of a derailed freight car. They should not extend more than twelve inches above the top of ties.

Lattice girders shall be so designed that the strains upon all members can be accurately calculated, preference being given to the Warren or triangular form of bracing. Intersecting diagonal members, riveted at the intersection, will not be allowed.

Each span of every structure shall have a cambre of $\frac{1}{1200}$ of its length.

To pass now to a description more in detail of the structure under consideration.

The pedestal piers mentioned consist of four courses of concrete, each 1 foot thick, the lowest course 8×8 feet in area, and each higher course 1 foot shorter in horizontal dimensions, the whole topped by a capstone in one piece. Built into the pedestals, heading on plates 1 foot from the bottom, are four 1¼ inches anchor bolts which fasten the cast pedestal down on the capstone.

The cast pedestals have bases 40 inches $\times$ 40 inches, are 3 feet 6 inches high, and have nowhere less than 1 inch thickness of metal. The pedestal completely envelops the post, which is fixed into the former by cement, composed of two parts of sand and one of Portland cement, topped with pure cement, this being considered preferable to iron filings and sal ammoniac sometimes used.

As to the vertical posts it is desirable to have them normally opposite for each pair, to obviate any lurch in fast running due to a point on one side of the bridge being on a post, and thus rigid, while the normally opposite point, not being directly supported by a post under it, would deflect. Simplification of the work, by avoidance of skew in the floor, and simpler provision for expansion and contraction, are further reasons why the posts of each pair should be directly opposite. Only at one place, at bent No. 1, are the lower tracks far enough apart so that the posts can come normally opposite, while each remains directly under the line of girders it supports.

This bent is braced transversely by means of two 1½ inch square diagonal rods each way; each post has also a longitudinal brace consisting of two 8-inch 25-pound channels. These braces extend in opposite directions from the bent, each brace being fastened at its foot to a masonry pedestal by means of anchor rods, which extend to a plate at the bottom of the masonry, in effect hanging the pedestal to the end of the brace, so that it acts as a counterpoise. While one brace acts in compression, the other is in tension, and vice versa.

At bents 2 and 3, one post is directly under the longitudinal girder, while the opposite one is outside of the bridge proper far enough to give by the skew of the lower tracks the required clearance from centre lines of said tracks. A cross girder connects the two posts, and supports the longitudinal girders. There being no room for sway rods, heavy gusset brackets are used to stiffen the connection of posts to cross girders. All vertical posts are built of two plates and four angles, latticed, the angles being turned outward.

The track enters the 82-foot span directly from a 6-degree curve. Fixed and sliding points for provision of contraction and expansion are taken as shown on diagram. It will then be seen that bent No. 1 has to resist the extra vibration due to train entering from curve, the push and pull due to both 82 feet and 53 feet spans being fixed on it, and the wind pressure from these two spans.

The ends of the bridge are squared, and rest on standard U abutments. Squaring of ends is in accordance with standard adopted for all Santa Fé system bridges. Short skew bridges are entirely avoided by carrying the respective corners of spans, that would otherwise be skew, to a square. In longer spans, where lengthening of spans would add largely to weight, the floor only is lengthened so as to carry it out to square ends.

The C., S. F. & C. coming over the bluff here is at a minimum elevation of 23.95 feet above the lower tracks, leaving, as 21 feet of vertical clearance is required, a minimum depth of 2 feet 11¾ inches of floor available. This allows for fairly economical proportioning of floor. In most of the other crossings only 26 inches of floor depth was available. Panel lengths vary from 16 feet to 17 feet 6 inches, being uniform for each span. Stringers attach to the webs of the floor beams. Lateral bracing is of angles, and attaches to the ends of the bottom flanges of the floor-beams; these lateral angles also rivet to stringers where they cross the latter. Sway bracing is effected by extending the upper flange and part of the web of each floor-beam outside of the trusses, and erecting on this a batter brace which fastens to the top chord of the truss.

Cross-section of floor is shown in Fig. 3. Ties are 8 inches × 8 inches

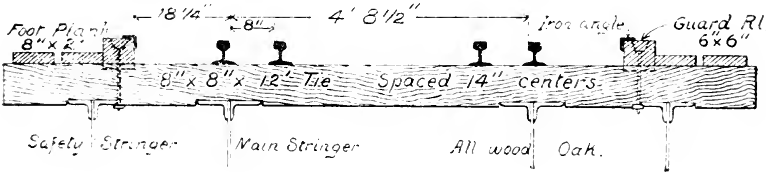


Fig. 3.

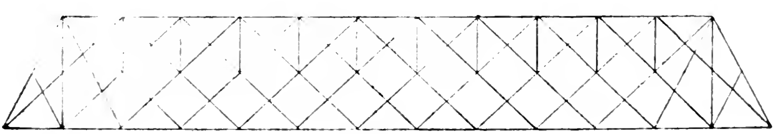


Fig. 4.

× 12 feet. let in 1 inch over stringers. Iron guard rail is 8 inches inside; wooden, bolted down with countersunk washers protected by iron angle, 18¼ inches outside of track rail, and outside of wooden guard rail there are two 8 inches × 2 inches walk planks.

The height of the 82-foot span, 9 feet 6 inches out to out of flanges, determines the height of the other spans, as it is desirable, for appearance, to have them uniform; for same reason length of this span determined use of lattice girder spans throughout the bridge, otherwise plate girders would have been preferable for the shorter spans. Top chords throughout consist of iron web plates, two or four angles, and one or more cover plates. Double webs in the chords would have been preferable for the 82-foot span considered separately, but would have given considerable excess of section for the shorter spans, so that for uniformity they were made single throughout. The web members, both tension and compression, consist of two or four angles, fastened to the web plates of flanges, generally by both legs of the angles.

Erection of Rock Creek crossing was a difficult piece of work, there being three lower tracks in constant use, and the upper one, to look out for. It was accomplished—the temporary wooden viaduct replaced by the permanent iron one—without interrupting traffic on the lower tracks whatever, and requiring but few stoppages, none exceeding an hour, on the upper track.

Total weight of iron in the structure is 350,200 pounds. It was furnished by the Rochester Bridge and Iron Works, of Rochester, N. Y.

In designing throughout, ambiguity is sought to be avoided as much as possible. For this reason the single intersection form of truss is chosen, and the Warren, or triangular lattice, works to best advantage. I should not hesitate to use this truss and make pony truss bridges, *i. e.*, bridges without overhead bracing, for spans up to 110 feet in length, if sufficient depth of floor to give proper stiffness was available. Where overhead bracing is once used, however, the pin connected bridge can be sufficiently braced, and gives in every way the most economical results.

Fig. 4 shows a type of truss often used for long span riveted bridges. In this form of truss, which is sometimes used up to spans of 200 feet, there are four distinct systems of transmission of strains. Objections to it are:

First. Its ambiguity. It is impossible to correctly proportion the web system, as it cannot be determined in what proportion a strain will traverse the different systems.

Second. Waste in tension members on account of rivet holes cut out, this waste being as much as 10 to 15 per cent.

Third. Waste in web compression members on account of not being able to use sections that will give economical proportions of diameter to length between supports, as they must be of such form that they will pass each other and pass into chords properly.

Fourth. Difficulty in getting good fit for field work and consequent liability to initial straining due to forcing of plates out of proper position to bring rivet holes to fit.

All these features detrimental to economical design are avoided in the properly proportioned single intersection in connected truss.

INSPECTION OF IRON BRIDGES AND VIADUCTS.

By B. L. Marsteller, Member of the Engineers' Club of Kansas City
[Read February 16, 1888.]

As few engineers have much shop experience, it occurred to me that this paper might be more entertaining if the association of the inspection of bridge and viaduct material be made with that of its construction, consequently I will briefly outline the course pursued in the inspection of thirty-five iron bridges and viaducts, built by the Keystone Bridge Company at Pittsburgh, Pa, for the Cincinnati Southern Railway, Mr. G. Bouscaren being consulting and principal engineer.

Mr. Bouscaren, wishing to have work done that would give results which could be relied upon, and being desirous to see this branch of engineering work raised to the standard which the necessities of the case required, arranged with the bridge company to make a number of tests of columns and bars, of such types as would furnish data for figuring determinately on the strength and other properties of American iron ; for the formulas in general use were those of Hodgkinson, Rankine and Gordon, which were established by tests upon a very different material. The results of Mr. Bouscaren's tests on columns have been employed by the late C. Shaler Smith in the preparation of his well-known formula.

Our first duty in the inspection was to check the working drawings with the strain sheets and specifications, or approved plans, and to see that the proper sections were given for channels, plates, bars and rods.

The next step was to determine from which pieces the tensile test specimens should be chosen, and to indicate the same in the bill of iron sent to the mill for each structure, noting at which place they were to be cut from the full size pieces and trued up for testing upon a Riehlé machine. This iron was required to stand 50,000 pounds per square inch, to reduce in area at breaking point 25 per cent., to elongate 15 per cent., and when cold to bend from 90 degrees to 180 degrees without sign of fracture.

All iron was to be tough and highly fibrous, of uniform quality, and capable of sustaining 25,000 pounds per square inch without taking a permanent set.

We weighed and calipered all channel and angle iron as it was unloaded in the yard of the bridge works, and all pieces scant in section three per cent. or more were immediately returned to the mill. After determining the dimensions we tabulated them, and used the tables instead of measuring the length of each piece and figuring the weight per lineal foot from the total weight of piece ; this we could do without making an error in excess of two per cent.

The necessity for some such means of determining sections in the shop is apparent when the shop's practice was to change section for two-tenths of a pound in a foot, and to have as many as twenty-two different sections in columns alone for one viaduct.

The iron first goes into the assembling shop. just inside of which there

is a gang of men who do the straightening, and next to whom is another who do the laying off. Next are two power machines, one for punching rivet-holes, the other for shearing; then comes another gang of men who set the pieces up and bolt them together for the riveters. Just across the track that runs through the centre of the building are hydraulic and power riveters, and gangs of men who do such riveting as the machines cannot do—such as that for bolsters and ends of posts, counter-sunk rivet-work, etc.

In this shop all rivets were tested by placing two fingers on one head and striking the other head right and left with a hammer. Any rivet found loose was marked with white paint, which was the sign for removal. All rivets were required to fill the holes completely, and to have well shaped treads opposite each other (*none on a bender being allowed*). Split lattice bars, broken rivet holes in plates or channels, spacings, sections, slots, expansion-joints, right and left hand members and imperfections in the iron, such as cracks, blisters and flaws, are here looked for: and each piece is either passed, condemned or sent to the blacksmith shop, but in any case so marked as to be always readily identified.

These pieces now go to the machine shop, the appointments of which consist entirely of lathes, planers, drills and cranes. Here the pin-holes are bored, bearing and abutting surfaces are planed, and pins turned. Pins were required to be of exact lengths, the diameters of pins and pin-holes not being allowed to vary more than $\frac{1}{100}$ part of their diameter. For making these measurements, the shop was well supplied with steel gauges of all sizes, and templets for planed surfaces. Pieces were here examined for length, $\frac{1}{64}$ of an inch being the maximum variation allowed.

From this shop the material was sent to skids in the yard, where some pieces having attachments that could not be made until they were planed were finished. This material was then soaked in boiled linseed oil, and all parts inaccessible after erection were given two coats of mineral paint. Pins, pin-holes and planed surfaces were treated with a mixture of tallow and white lead. After this all the iron thus inspected and passed was branded C. S. Ry., by stamping.

We now pass to the forging or blacksmith shop and bolt and testing room, where chord and suspension bars, lateral rods, knee-braces, portal trimmings and many other things of like nature are made.

The truss bars were bored in the bolt room. There was always one piece of each length accurately laid off and bored, then used in boring all others of the same length by piling and fastening all together, the drill passing through the one previously bored. As both ends were bored at the same time, many errors were evaded, and accurate lengths were obtained. The adjustable members were examined for lengths, size, upset and welded ends, sleeve-nuts, threads, etc.

The chord and suspension bars were tested for modulus of elasticity, the elongations being taken with a machine designed by Mr. Bouscaren. (See sketch.) The elongation was taken for a length of 10 feet between an initial pressure of 10,000 pounds and a terminal pressure of 20,000 pounds per square inch. The modulus was then worked out and stamped into the bar, and when the iron went to the

field, bars having to work together as one member were selected with reference to their moduli. One main object in this test was to show up any defect in the bar that could not be detected by the eye. The testing machine was so gauged as to indicate ten times the actual elongation of the bar, consequently the latter could be determined to the $\frac{1}{1000}$ part of an inch, which was the greatest permanent set allowed under the above mentioned intensity of stress. The machine would therefore show whether any set had taken place on the removal of the stress.

Now we can pass to the other end of the hydraulic testing machine and break a column. The latter is placed in the machine with channels in a horizontal position, and counterbalanced at the centre to the extent of one-half its weight. A steel measuring rod slightly shorter than the column is placed on the top channel, which is chalked and marked at the end of the rod with a fine pointed tool so as to indicate compression readings, arrangements being also made to take horizontal and vertical readings. For an example we will take a column built of two 12 inch channels latticed on two sides, flat ends 27 feet 7 inches in length, finished weight 1,540 pounds, with a sectional area of 13.77 square inches. The first stress applied was 500 gauge pressure, which equals 130,000 pounds, the gauge indicating the pressure per square, on the piston, the area of which was 260 square inches. Readings were taken at each increment of 100 gauge pressure.

The deflections for the above 130,000 pounds were $\frac{1}{4}$ inch horizontal and $\frac{3}{32}$ inch vertical, and the compression was $\frac{1}{8}$ inch.

At 273,000 pounds pressure the horizontal deflection was $\frac{3}{16}$ inch, the vertical deflection $\frac{3}{32}$ inch, and the compression $\frac{1}{4}$ inch. When the stress was removed, the readings were as follows: Horizotal permanent set, $\frac{1}{32}$ inch: vertical set, $\frac{1}{32}$ inch: compression, zero.

At 442,000 pounds pressure: Horizontal deflection, $\frac{5}{16}$ inch: vertical deflection, $\frac{1}{32}$ inch: compression, $\frac{12}{32}$ inch. Stress removed: Horizontal set, $\frac{1}{4}$ inch: vertical set, $\frac{1}{32}$ inch: compression, $\frac{7}{32}$ inch.

At 445,900 pounds pressure the column gave way, after maintaining it for a few minutes. This corresponds to a pressure of 32,300 pounds per square inch of section.

This hydraulic testing machine had a capacity of 1,000,000 pounds, and, I believe, was a product of the shop.

The tensile specimens broken at the mill were generally from $\frac{1}{2}$ to $\frac{3}{4}$ square inches in section, the reduced section on which was marked the length for measuring the elongation being from 5 inches to 6 inches long, with the shoulders next to the grip ends beveled off. The ultimate strength developed was from 51,000 to 53,000 per square inch. Many full-size brass bars were broken, and at first the larger percentage of them gave way in the eye, the process of making the head being to upset the bar and forge the head down with a steam hammer to the exact size. Now they pile the head and forge it to the proper dimensions in a die with a ten-ton hammer, and it is only in rare instances that a bar thus manufactured breaks in the head. The ultimate strength of those breaking in the body of the bar was from 46,000 to 48,000 pounds per square inch of sectional area.

Professor J. B. Johnson, of Washington University, St. Louis, says that the length of reduced area of specimens for tensile stress should be expressed in diameters of the reduced section, as the ultimate strength, percentage of elongation, or reduction of area, may be varied from ten to fifty per cent. in the preparation of the specimen; that brittle material, such as cast iron and hard steel. should have the grip ends trued up in the lathe or planer, so that the grips will not throw the piece out of line; and that if the reduced section be made with square shoulders, the deeper the cut the less will be the developed strength of the specimen, for the stress in the exterior fibres of the grip ends is suddenly concentrated at the shoulders of the reduced section and transmitted to the reduced section through its exterior fibres, and these fibres not being able to stretch out as they would in wrought iron, the piece begins to rupture at the shoulder before the internal fibres have been brought to their full strength. In this case the length of reduced area is not a consideration of much importance, as the elongation and reduction of area are almost inappreciable, two or three diameters being as good as more; but in wrought iron and soft steel the reverse is the case.

Material which is ductile will stretch from 10 to 30 per cent. before it ruptures, and will draw down or become very much reduced in size at the point of rupture if the reduced section is long enough to admit of it; but if it be very short the fibers are supported by the outer fibers of the end sections, and for this reason will not stretch so freely as in longer sections. If this stretch and consequent reduction are prevented by the reduced section being short, it is evident that the ultimate strength will be greatly increased; and, if the specimen elongated uniformly, this ratio would be a constant for all lengths; but the specimen draws down or stretches more at the point of rupture than at any other place, the length of the greatly drawn down portion being usually from two to three diameters of the specimen; therefore to obtain uniform or comparable results, the length of the reduced section should be made a certain number of its diameters. He recommends for all specimens that the length of reduced section be eight diameters, that the reduced area be not less than 80 or 90 per cent. of the grip area, and that the shoulders be cut to a curve of a two-inch radius.

There is one more test of which I wish to speak before bringing these few remarks to a close, viz., the live load test made of the channel span of the Ohio River bridge. There were ten spans tested at the same time, but this one will illustrate the whole.

This span had 5 inches of camber, and the camber line passing through the centre of pins in the bottom chord under the specification was not to vary more than one quarter of an inch either way from an arc of a circle.

Engines headed north, engines and cars given in the order of position from north to south.

Two platform cars, engines Nos. 3, 6, 9, 4, 8, 1, 12, two platform cars second truck wheel of engine No. 4 over middle of span.

Live load on span between centres of end pins, 255,100 pounds.

Length of span, centre to centre of end pins, 515 feet.

Deflection: East truss, 2.20 inches; west truss, 1.98 inches.

Elongation at roller end of bottom chords: East truss, 0.56 inch: west truss, 0.57 inch.

Load removed.

Permanent deflection: East truss. 0.06 inch; west truss, 0.012 inch.

Permanent elongation: East truss. 0.075 inch; west truss, 0.05 inch.

Same span, train of two engines and four flat cars, moving backwards 25 miles an hour.

Live load, 391,300 pounds.

Deflection: East truss, 1.2 inches; west truss, 1.2 inches.

Expansion at roller end of chord: East truss. 0.25 inch; west truss, 0.25 inch.

No permanent set visible on removal of load.

DISCUSSION.

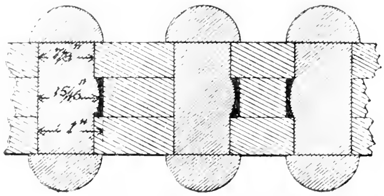
By W. H. Breithaupt.

I have been greatly interested in the valuable paper to which we have just had the pleasure of listening. The correct and faithful carrying out of a bridge design in its manufacture in the shops is of the utmost importance, so much so that a good bridge may be said to depend on it almost as much as on proper design; and this is now so well recognized that thorough inspection is almost universally insisted on for all work that is to be reliable. This matter of thorough inspection is, however, of comparatively recent growth; we are not yet so very far from the day when iron was iron with hardly any distinction in quality. The Cincinnati Southern Railway Company was among the first in this country to insist on thoroughness in quality and manufacture of bridges. But entering a comparatively new field, with but little of the mass of evidence that has mostly since accumulated at its disposal, some things were required which are now not required, and others are now more strongly insisted on than they then were. I will dwell on a few of such things as brought forth in the paper of this evening.

As to quality of iron a number of classes are now specified: Purely tension iron, shape iron, edgerolled plate and sheared plate, requirements ranging from ultimate strength, 52,000; limit of elasticity, 26,000; reduction of area, 25 per cent.; elongation in 8 inches, 18 per cent. in purely tension iron to Ult. 46,000; L. E., 25,000; Rdn. 12 per cent.; El. in 8 inches, 8 per cent. in sheared plate over 54 inches wide, such as is used only in girder webs. In channels and I beams requirements are higher for the material of the flanges than for that of the webs. Shape iron as it comes from the mill is generally classed by its weight per yard, a certain weight corresponding to a certain size and thickness. Weights from the various mills differ slightly for same size and thickness, depending on slight modification in shape. These weights must agree with what is called for within 2½ per cent., and they generally come closer. On a recent bridge which I computed, weighing some 5,000,000 pounds, the total calculated weight of the finished bridge agreed within about 1¼ per cent. with the scale weight.

Good riveting is an important feature, and is generally very fully specified. I was recently shown an interesting riveting test. Three short plates had been riveted together, the rivets in line, the holes in the outer

plates of like diameter, but in the middle one of larger diameter (see the figure) to ascertain how much the rivets would fill them out. On plates being planed down on edge until diametrical section of rivets was exposed, it was found that rivets had not expanded in the larger central holes more than $\frac{1}{16}$ inch, and this after the utmost care had been exercised in driving them, the rivets having been well heated and then cooled at ends, so as to act better on hotter central part where they were to expand most. This test refutes the often expressed idea that a well driven rivet will fill out holes of diameters varying by $\frac{1}{8}$ inch or more.



As to checking of lengths and sizes, $\frac{1}{50}$ inch divergence in main pinholes or pins, and $\frac{1}{32}$ inch in length of eyebar, post, or chord section is now allowed.

Painting between surfaces that are to be riveted together needs to be carefully looked to. There should be one good coat of paint on each surface before pieces are assembled for riveting. Linseed oil coating is very good in that it leaves any defects apparent, but most engineers specify paint. All defects should be detected by inspector before painting is done.

A feature of importance, and sometimes difficult to obtain, is to have stiffener angles that are put on webs of girders fit closely into the flange of the girders. They should be cut slightly full in length, so as to necessitate their being driven to place, and should have edge of one leg of angle beveled off so as to fit against fillet of flange angle.

Very few, if any, recent bridge specifications require the determination of modulus of elasticity. Practical determination of this property led at best to very unsatisfactory results, as its correct determination required an extreme care seldom given it. Ductility and elasticity of the material can be fully determined by the regular tensile and bending tests.

Initial straining of the finished eyebars is also no longer considered necessary. Specimen tests on the material, confirmed by a number of selected tests on finished bars, give with the present uniformity in manufacture, full information as to quality, without subjecting each finished bar to fully twice the strain that should ever come on it when doing its duty in the structure, as former specifications required.

Eyebars, except for very light work, are now preferably made of mild steel, and for these the head must be formed entirely by upsetting on the bar. Some engineers still insist on iron for all bars, but with the uniformly good steel that can now be had, and the improved methods of working it, the prejudice against its substitution for iron in purely tension members is fast disappearing.

Mr. Marsteller gives the live load on a span of 515 feet as 955,100 pounds. A modern load, two 86-ton engines, followed by a train load of 3,000 pounds per foot, gives 1,577,000 pounds for such a span.

Camber of 5 inches in 500 feet or 1-1200 of span is still considered good practice. The idea is to have the camber so that with maximum load on the span deflection shall not be more than the allowed camber.

In a paper recently read and discussed before the Engineers' Club of Western Pennsylvania, Mr. Ramsay, Chief Engineer of C. H. & D. Ry., brought forth the fact, varying from accepted ideas, that some iron giving, when tested at ordinary temperatures, results fully up to requirements, would at low temperatures give entirely different results. A large number of tests was made, and so the fact was fully established. In a series of such tests, of which the experimenter, Mr. A. E. Hunt, of Pittsburgh, told me about 40 per cent. gave the same results at low as at high temperatures, while about 60 per cent. varied, giving at high temperature ordinary good results, while at low temperature much lower results in ductility, but slightly higher in Ult. and L. E. Chemical analysis failed to show any difference between the material which gave uniform results at varying temperatures and that which did not. Another experimenter found that large squares gave more divergent results at varying temperatures than smaller ones; in other words, the material which had received more work in the rolling was not so much subject to change with changing temperature as that which had received less, but this was not uniformly so. On the whole, no satisfactory reason for these results and consequently no remedy were arrived at. What seems to be fairly well established is that the material of all bridges is apt to be somewhat brittle in cold weather, *i. e.*, the material is less ductile. It is, however, at the same time slightly higher in ultimate strength and limit of elasticity. Advisable precaution is to avoid maximum impact by running trains slowly over bridges when the temperature is very low.

By Henry Goldmark.

It is gratifying to find the subject of bridge inspection receiving more attention from representative engineers than it has in the past. Mr. Marsteller, in his interesting paper, has given an account of the methods pursued by him and his associates in superintending the building of one of the earlier bridges. Since that time the importance of a close and intelligent supervision of such structures during the process of manufacture has become more generally understood by railroad companies.

Though many bridges are still purchased by relying solely upon the good faith of contractors, most large spans are now built under systematic inspection in the rolling-mill and shop, and on the erectors' scaffold. The profession owes much to the efforts of those of our leading engineers, who, in spite of many difficulties, have insisted on raising the standard of excellence in bridge work. In the long run, exacting specifications closely adhered to have proved an advantage to contractors as well as to buyers, as the line of division has become more strongly marked between those able to do first-class work and those who are not.

The inspector, to accomplish his task with success and with fairness to

all parties, must have experience and tact, but, above all, must be thoroughly conscientious. As a matter of fact, it is often impossible to tell from the appearance of a finished structure whether the supervision has been thorough or merely nominal, but the difference in the safety and life of the work is often very great.

The work of inspection falls naturally and not improperly into the hands of the younger engineers, and they need all the "backing" they can get from their superiors in office, in order to make themselves respected and successful in the execution of their duties. It is in this direction that there is, I think, room for improvement in many cases.

As to iron bridges in actual use, the importance of regular examination by experts seems to be as yet little understood. As they form part of the road-bed the tendency is to treat them like any other permanent structure on the line, subject to static loads only. A new coat of paint at rare intervals, and new ties when the old ones are absolutely unsafe, are often the limit of the care bestowed upon them.

When we consider the numerous and important movements, both molar and molecular, to which the metal is subjected, it seems unfair to expect long life or satisfactory service from bridges which are not kept in thoroughly good repair, and strengthened when called upon to carry loads much heavier than those they were designed for.

There are one or two points in Mr. Marsteller's paper which are of special interest in comparison with later experience.

The "reduction of area" in small tension specimens of iron and steel has given as much trouble as a requirement for acceptance of material as any other point in bridge specifications, and it seems to me, with little advantage. This quantity is, of course, in a general way, a measure of the ductility of the material, and, as such, is closely related to the stretch parallel to the axis of the piece. But while the elongation is readily defined in terms of the ratio of length to breadth, the amount of "drawing down" seems in many cases to be influenced by accidental causes. Much good iron and steel has been rejected on account of failure in this test, and it is at least debatable whether it is not best to drop it entirely from our specifications.

Another point of much interest is the question of "Modulus of Elasticity." In the theoretical discussion of the resistance of materials the modulus is perhaps the most important factor. It is the only guide to the determination of all strains in members which cannot be found by simple statics, and there are, doubtless, many such strains, in even the most scientific designs. In the important subject of long columns it has served a most useful purpose in guiding experiment and observation.

The attempt which Mr. Marsteller speaks of, of selecting iron of the same modulus for the same parts of his bridge, is an interesting historical point. It does not appear to have been very successful, nor can it be defended in the light of later experiments.

As a matter of fact, I do not think the modulus of elasticity need play any important part in practical testing. It is, without any doubt, the most constant quantity in all grades of steel and iron, and for that very reason unfitted to serve as a test for the acceptance or rejection of any one lot of material.

TESTS MADE ON IRON FROM PENCOYD IRON WORKS, FOR VAN BUREN BRIDGE, ST. L. & S. F. RAILWAY, ON GILL MACHINE, JOHNSTON, PA.

TEST PIECES CUT FROM	Cross Section.	Elastic limit. Lbs. per sq. in.	Ultimate strength. Lbs. per sq. in.	Elongation in 8″. Per cent.	Reduction of area. Per c't.	Modulus of elasticity.
6″ × 6″ × 5/8″ angles	1″ × 5/8″	31,910	50,590	24.1	22.9	29,910,000
" " "	"	33,030	50,980	16.1*	23.0	29,510,000
" "	"	31,460	50,480	23.6	29.4	29,840,000
6″ × 4″ × 1/2″ "	1″ × 1/2″	30,940	51,060	19.0*	24.0	29,000,000
" "	"	33,670	51,390	23.6	31.2	28,130,000
5″ × 3 1/2″ × 9-16″ "	1″ × 9-16″	31,880	50,470	21.9	27.4	28,310,000
" "	"	29,190	45,870	18.6†	27.6	28,760,000
" "	"	32,510	52,410	25.7	35.6	28,690,000
" "	"	30,250	45,910	17.4†	....	29,250,000
" "	"	29,530	50,290	26.8	32.1	29,830,000
5″ × 3 1/2″ × 3/8″ "	1″ × 3/8″	32,680	46,840	13.4	20.4	28,110,000
" "	"	33,210	50,510	18.1	18.5	29,280,000
4″ × 4″ × 3/8″ "	"	33,040	51,760	15.5	26.6	29,550,000
" "	"	33,980	52,100	21.5	37.8	28,350,000
4 1/2″ × 3″ × 3/8″ "	"	34,960	50,770	19.1	16.8	28,330,000
" "	"	35,460	46,450	8.7†	18.2	27,620,000
3 1/3″ × 3 1/2″ × 3/8″ "	1″ × 3/8″	37,750	58,430	22.9	28.8	30,510,000
" "	"	35,720	51,600	15.1	20.6	28,500,000
" "	"	31,840	45,470	9.0‡	20.8	28,430,000
" "	"	34,430	52,070	18.0	22.2	28,220,000
3″ × 3″ × 3/8″ "	1″ × 3/8″	36,590	55,730	15.6‡	16.9	29,240,000
" "	"	35,010	53,080	14.0	17.1	28,350,000
3″ × 3″ × 5-16″ "	1 1/4″ × 5-16″	37,010	53,420	15.4	23.6	28,780,000
" "	1″ × 5-16″	37,080	53,400	12.3	19.1	26,740,000
12″ × 21-32″ channel flange	1″ × 5/8″	32,000	52,200	26.4	40.8	29,540,000
" " web...	1″ × 21-32″	30,910	52,320	21.5	24.9	27,570,000
12″ × 9-32″ " flange	7/8″ × 5/8″	33,560	51,820	18.6	26.7	27,270,000
" " web...	1 1/4″ × 9-32″	34,430	51,520	17.3	20.4	29,150,000
10″ × 1/4″ " flange	1″ × 1/2″	34,020	52,530	25.3	30.2	29,080,000
" " web...	1 1/4″ × 1/4″	36,770	52,530	14.5†	17.7	28,740,000
5″ × 1 1-16″ bar............	7/8″ round turned.	31,150	49,920	21.4	29.1	29,140,000
" "	"	29,850	46,480	26.5	41.6	27,510,000
4″ × 1″ "	"	32,750	51,800	25.1	32.0	28,430,000
" "	"	28,880	50,230	25.8	35.5	28,580,000
" "	"	31,290	50,940	28.1	45.8	28,490,000
" "	"	33,610	52,570	24.3	39.6	30,370,000
" "	"	29,170	47,670	27.5	41.2	28,230,000
" "	"	33,940	50,990	26.0	35.4	29,270,000
" "	"	31,420	50,460	25.7	28.2	29,440,000
5″ × 1 1/3″ "	"	31,310	50,420	25.0	36.6	28,820,000
" "	"	32,290	52,160	26.1	35.3	28,490,000

* Broke in grip. † Broke in flaws. ‡ Broke near end of specimen.

Bending tests: A piece cut from the same bars as above test pieces was bent by a steam hammer, nearly 180°, about a 1 1/4″ pin, without failure. The fracture of the iron was fibrous.

The long series of tests made at different steel works seem to prove conclusively that even for the widest variations in the percentage of carbon, the modulus of steel is practically the same.

Tests made on many thousands of small bars at the testing laboratory of the Cambria Iron Co., at Johnstown, Pa., establish the fact beyond question that the elastic modulus of steel lies somewhere between 28,000,000 and 30,000,000. Several papers by Mr. C. A. Marshall, C. E., Engineer of Tests, may be referred to in support of this view.

In the case of iron, the observations of the modulus, at least on small specimens, are less numerous than those on steel. I do not know that it is possible to make as definite a statement on this point as in the case of steel. Many recorded experiments certainly seem to point to a much greater variation in the modulus. It is only fair to remember, however, that

the earlier instruments were far less accurate than those now in use. From such experiments as I have been able to make myself, I feel satisfied that in the best grades of eyebar and angle iron, the modulus is but little lower than that of steel and equally constant. In poor plate iron, I have found the results lower and more variable.

I may be allowed to add to these few remarks some tests made on iron bars a year or two ago, in the regular course of my work, which may throw some light on the subject. They relate to specimens of a most excellent iron, for the results of a long series of tests on material for this bridge (the Van Buren Bridge, St. Louis & San Francisco Railway), and show equally good results.

The tests were all made in the testing laboratory at Johnstown, and the modulus was carefully determined with the very neat and accurate micrometer designed for this purpose by Mr. Marshall, and described by him in the *American Engineer*, August 27, 1885, vol. 10, page 84.

CLASSIFICATION OF MATERIAL IN RAILROAD CONSTRUCTION.

By A. M. Van Auken, Member of the Western Society of Engineers.
[Read July 18, 1888, and held for discussion September 5.]

If there is any one thing in railroad construction on which the novice is wholly at sea it is apt to be the classification of material, and the young engineer who "was not familiar with the nature of loose rock" deserves full as much sympathy as ridicule. We have all heard of him, and while some of us may have been less laughed at, is this not because we have been less honest?

The most common form of specification divides material into three general classifications, earth, loose rock and solid rock, and ordinarily specifies that earth shall include all material of whatever nature that can be ploughed and scraped into an embankment; loose rock, all boulders containing from one cubic foot to one cubic yard, all cemented clays, hardpan, sand rock or other stratified rock which cannot be removed without picking, but can be removed without blasting, although powder may sometimes be used; and solid rock includes all boulders or detached masses of rock containing over one cubic yard, and all material which in place cannot be removed without a liberal use of powder.

On some roads earth is subdivided into borrow, waste excavation and gravel, and loose rock into hardpan, soft rock and loose rock, but contractors in bidding are apt to ignore these subdivisions and make prices nearly equal.

Under these specifications there are times when the proper classification is so apparent as not to admit of doubt. When it is apparent that earth must be borrowed below water, when it is apparent a spring will give trouble in a cut, when on the surface a cut shows to be full of boulders too small to classify, but large enough to become very troublesome, and when from any other cause it is evident before the work is opened that it will be difficult work, no contractor has a just claim for any stretching of the specifications. He is expected to be diligent and

wide awake. If he agrees to do a thing for a price which entails a loss, when the nature of the work could be known in advance, he will learn the truth of the old saying that "experience teaches a dear school, etc."

But there are thousands of instances where it is not easy to classify. A cut looks fair to the eye on the surface, but as it is opened develops springs, small boulders in abundance, or some other trouble not to be guarded against. There is one chief engineer who classified such material as "hard luck." Probably he enjoyed the humor more than the contractor did.

Again, there is a line which divides loose rock from solid rock. Loose rock is any rock which can be removed without the use of powder even though powder may have been used. There is a sort of sand rock in Wyoming and Colorado which, when first exposed to air, has a hard, blueish look, cannot be phased by the pick and will break drills, yet after it has been exposed to air a time will turn so soft that the waste dump appears but a heap of sand, and a slope in cut of less than 1 to 1 will not stand. Again, in the beds of old water courses there is frequently found a cemented gravel formation more difficult to move than solid rock, and yet when it is once moved it will blow away in the wind. This material is difficult to blast because it is next to impossible to get a hole drilled, the material continually falling around the drill.

Under these conditions what is it our duty to do?

Mr. Shunk's rule, as given in the instructions to the engineers on the South Pennsylvania, were (as I remember them): "It is your duty to classify material as you find it. Any extra allowance for unforeseen difficulties must be left to the parties who pay the money."

My first superior used to say: "If material costs as much per yard to move as does solid rock, give them solid rock." By this he did not mean that it was our duty to classify work by what it cost them to do it, but that if it cost a man eighty cents per yard to move what was undoubtedly solid rock, and thirty cents per yard to move what was undoubtedly loose rock, and a cut of this mixed material should cost forty-six cents per yard to move, it was our duty to give him a classification of one-third solid rock and two-thirds loose rock.

Be this as it may, there is one simple duty for us to perform, so simple that we should *never* neglect it, and that is to keep such a force account as will enable us to know very closely how much a piece of work has cost the man doing the work. I would keep this by sections, or by smaller divisions if a contractor have less than a section. I would also have it so subdivided as to show as nearly as might be the cost of each branch of labor. Take a field book and head it as shown on the following page.

In this list include everything. If teams are required to haul water, keep them under head of freight teams. If teams are sent to nearest railroad station to bring in men, classify them as freight teams and give them their time. If laborers are scarce and the contractor keeps a man out "hustling" for men, put him into the column of non-producers, which will give about the wages he is paid, and if he has a horse or team, give time for that also. I would prefer classing a team as without a driver. And make your prices what will cover actual cost to contrac-

tor. Put in book-keepers, foremen, blacksmiths, etc., at average wages, and the rockmen and laborers at wages actually paid. Make an effort to keep producers and non-producers apart. Foremen, book-keepers, cooks, carpenters and blacksmiths are necessary and save money, but do not produce. Ordinarily it shows bad management when over 10 per cent. of expense is for non-producers. For the teams, make an arbitrary price somewhat larger than judgment shows is needed to feed the team and pay for wear and tear and depreciation of harness and tools. Bear in mind that team must be fed for seven days each week even if worked but six. The wear and tear and depreciation of harness and tools may be roughly assumed at about fifty cents per horse per day on carts, the same per team on wagons, plows, stone boats, etc., and from fifty cents to one dollar per day on drag and wheel scrapers according to material. Difference of material on plows will be made up by having more teams per plow where material is harder on tools. If a man hires teams, make no difference in your list. Keep a correct list of all his men and teams at what he has to pay men and cost of teams. If a man hires teams at a profit he becomes in the nature of a sub-contractor, and his profit should be no part of actual expense, which this account is designed to show.

FORCE ACCOUNT, ON SEC. 16, WILLOW CREEK EXTENSION, JUNE, 1888.

DATE.	Foremen and book-keepers at $— per day	Rockmen at $— per day	Laborers at $— per day	Bl'cksmith and carpenters at $— per day	Cooks at $— per day	Waiters, call boys, etc., at $— per day
June 1...........						
2...........						
3...........						
30...........						
Total amount.						

DATE.	Plow teams at $— per day	Scraper teams at $— per day	Carts at $— per day	Wagon teams at $— per day	Freight teams at $— per day	Remarks.
June 1...........						
2...........						
3...........						
30...........						
Total amount.						

Take all possible pains with this report, and as the work is completed compile it in a more compact form, so as to still show amounts paid for both producers and non-producers, and on comparing with the final estimate it will show the loss or profit on the work, and if a loss will show just where it occurred. You will be apt to know as near as the contractor where he lost or made his money, and should the case ever come before a commission or into courts the moral effect of this showing would be beyond estimate. In addition to this, keep a diary in which you note each day something about the work, keep a rough check on the force

employed at each cut, the date opened and when finished, get as closely as possible the amount of powder used in it, and all data that will help you to get the actual cost of the cut. For instance, on Monday there is one foreman, thirteen men and two carts in the east end of a cut; one foreman, eleven men and two carts in the west end, and the two have a boy between them carrying water and carrying steel, picks, etc., to and from the blacksmith. You make this entry in your diary, and also any note about the nature of the material the work is then in. Suppose it is Thursday before your duties allow you to see the cut again. You count your force again, and note that in the meanwhile a hole has been fired for loosening the material in the cut which contained four kegs of black powder (or whatever amount has been used), and that a certain number of sticks of giant have been used breaking up large boulders. When the cut is completed. by compiling these notes you know what the cut cost and by dividing cost by number of yards in cut can get cost per yard. This should be noted in your estimate book as the "actual cost to contractor of doing this piece of work." Adding any incidental items of cost not already in, such as freight on material, portion of the blacksmith's time, depreciation of tools, etc., and adding 10 per cent. to the whole amount for contractor's profit, and we have what the man can reasonably expect for his work. If your judgment will allow it, I would classify up to this price.

With such data as this, which should all be compiled when work is completed and filed away in some well-bound book which you can index, you will in a few years have such an amount of data on cost of work as will be invaluable. It will often allow you to judge in advance of the probable depth of insolvency the sub-contractor will find himself in at the end of the work.

Classification would be very much less difficult if more of our roads would abandon the utterly iniquitous method of letting work to the lowest bidder, or would let only so much work to one man or firm as they can personally do with the outfit they possess.

As a rule the lower a price the principal contractor bids the more ignorant, dishonest and poverty stricken, as a class, will be his sub-contractors. About the second monthly estimate will, if it be truthfully given, bankrupt the whole outfit. But now the company has become anxious to rush the road to completion. The very shrewd head contractor, who foresaw this, gets the ear of the President, details the unforeseen difficulties encountered on the work, which have very greatly increased the cost, etc., etc., tells him that his men are becoming clamorous, hints at delays, a possible difference of opinion on some clause, and the President, who really fears the shrewd man he is dealing with, is persuaded to issue an order to the chief engineer to "see the men out whole." This order may be verbal, and the chief may give a similar verbal order to his subordinates, and if trouble were to occur in the directorate, and an investigation were to follow, the characters and the ability to earn a living in the future of these engineers depend on the manhood of the President in a time when his whole future may seem in the balance. But leaving this aside, the work has been done by an inferior class of men, has not been done well or with a

proper regard for economy, and while the chief contractor has made a profitable summer, the work has cost the company from ten to twenty per cent. in excess of what better work properly let would have cost. Any chief engineer fit for the position he holds knows what it is worth to do work, and when a railroad corporation, in defiance of his opinion or in ignorance of it, let work at less than it can be done for, they are very unwise, and it will end as noted above, or the road will be built by contributions of unfortunate, and, as a rule, hard working subs. Neither of these appear candid nor honest. But, by following directions given in the body of this article, you will have a sufficient data for your acts, and can show good reasons for all you have done. A few roads have such a conception of an engineer's duties that they furnish no instrument man, and give him such an amount of work to do as keeps him a good portion of daylight out doing instrumental work. It will in this case need some scheming to get your time properly kept, but you can get a passable record by ruling a sheet such as I have mentioned, and leave with each of the timekeepers on your work. Get him to fill it. Then, by counting yourself whenever possible you get a check on him and can get a very fair time sheet. On compilation of diary entries of cost of a cut, I have sometimes, when my check was not very good, added ten per cent. to the number of laborers to cover error, preferring to have the cost somewhat large to taking any chance of its being small.

COMMISSARY.

In working a crew of men one of the very important things is feeding them. Where the country is settled this is generally solved by boarding the party among the inhabitants, and it takes from the chief of party a worry and burden. But where the outfit and supplies are carried along a new duty is laid on the chief. Passing over the annoyance usually experienced with a cook, who is usually either worthless and unreliable or else unable to cook, there is a wide question before him of what to buy. And the man who has always been finding fault with hotels comes to have a deep respect for a caterer. On river work of the U. S. Engineer Department it was the rule for the men to buy the supplies, which were charged up to them by the number of meals each one had. One of our cooks made it cost us $13 per month, and another one on the same piece of work fed us as satisfactorily at a cost per man of but $7. Another instance in Minnesota, a locating party cost the company $25 per man per month, while an equally well satisfied party on a line near by cost but $9 per man. In this last case the $25 man bought boxes of jumbles of country stores, which crumble badly and are largely wasted and cost high, and canned fruit at similar places, which is high of price and inferior of quality. Lay it down as a rule to buy your supplies of a wholesale house at the largest town you have access to. You will save somewhat in price but gain very much more in quality.

And then remember that the highest priced commodity you get is bacon. Do not allow yourself to think that by feeding your men largely on bacon and beans you are feeding them cheap. Sugar and syrup are far cheaper.

When in the woods of Wisconsin, Michigan and Minnesota I was sur-

prised many times at the loads our packers carried and the small amount *in weight* which they ate. Yet that amount was largely sugar. I have been told by these men, half-breed Chippewa Indian and Canadian French, that the Indian messengers, or "runners," ate on their trips a mixture of corn, parched and pounded, and sugar, equal parts of each. The trips made by these men are unparalleled, and yet a meal was equal to about four tablespoonfuls of this mixture.

In my early experience I sought some guide on the matter of supplies, and found in Burt's work on the Solar Compass a list which, when reduced to rations for one man one month, is:

Flour	66	pounds	Rice	1	pound
Clear pork	31	"	Salt	1	"
Beans	$7\frac{1}{2}$	"	Pepper	1-24	"
Dried apples	5	"	Castile soap	1-6	"
Sugar	5	"	Matches	1 box	
Coffee	3	"			

At the time this list was made, there was a tax on matches. It is a list which shows how the men lived who surveyed the townships in the pine regions of the Northwest. It is fare which will sustain life, but it will not allow much washing of clothes. It is food not hard to transport, and as little likely to spoil as can be got. These are its merits.

The only other list I have seen in print is given in Mr. Cleeman's work as "U. S. Army" rations. It is:

$\frac{3}{4}$ pound pork or bacon, or $1\frac{1}{4}$ pounds fresh or salt beef.
$1\frac{1}{8}$ pounds bread or flour, or $\frac{3}{4}$ pound hard bread, or $1\frac{1}{4}$ pounds cornmeal.

And at the rate of one hundred rations:

Beans	15	pounds	Vinegar	4	quarts
Coffee	10	"	Candles	$1\frac{1}{2}$	pounds
or Tea	$1\frac{1}{2}$	"	Soap	4	"
Sugar	15	"	Salt	2	quarts

Reducing this to supplies for one man thirty days would give about:

Beef	$37\frac{1}{2}$	pounds	Sugar	5	pounds
or Pork	$22\frac{1}{2}$	"	Vinegar	$1\frac{1}{3}$	quarts
Flour	34	"	Candles	$\frac{1}{2}$	pound
Beans	5	"	Soap	$1\frac{1}{3}$	"
Coffee	$3\frac{1}{3}$	"	Salt	$2\frac{1}{2}$	"
or Tea	$\frac{1}{2}$	"			

This will allow a little more washing than the other, and will fill the inner man, and where transportation is a great object it might do. It would not be especially cheap and would be pretty poor living.

I worked under one chief of party who used the following list. It was in a country where everything was packed in on men's backs, and he was well satisfied with it:

RATIONS FOR ONE MAN THIRTY DAYS.

Flour	32	pounds	Coffee	3	pounds
Ham and bacon	$16\frac{2}{3}$	"	Tea	1	"
Canned beef	4	"	Condensed milk	4	"
Dried beef	4	"	Salt	3	"
Boned codfish	4	"	Baking powder	1	"
Crackers	3	"	Saleratus	$\frac{1}{8}$	"
Ginger snaps	2	"	Yeast cakes	1	ounce
Oat meal	6	"	Pepper	1	"
Butter	$3\frac{1}{3}$	"	Mustard	2	"
Lard	2	"	Soap	2	pounds
Sugar	9	"	Candles	2	"

I got a cook in my employ to make me out a list to be used on con-

struction work where it was possible to get in with teams, but was over very bad roads. It was :

SUPPLIES FOR ONE MAN THIRTY DAYS.

Flour	35	pounds.	Butter	5	pounds.
Ham	20	"	Lard	2½	"
Bacon	5	"	Evaporated apples	1	"
Canned beef	5	"	" peeled peaches	1	"
Dried beef	3	"	" raspberries	1	"
Oat meal	6	"	" cherries	1	"
Corn "	4	"	Raisins	1	"
Navy beans	6	"	Pepper	1	ounce.
Sugar	10	"	Mustard	1	"
Coffee	4	"	Ginger	1	"
Tea	¾	"	Cloves	1	"
Rice	2	"	Lemon extract	1	"
Corn starch	¾	"	Vanilla "	1	"
Salt	2	"	Yeast cakes	1	"
Condensed milk	3	"	Soda	1	"
Soap	2	"	Baking powder	½	pound.
Candles	3	"	Matches	1	box.
Pickles	1	quart.	Syrup	½	gallon.
Vinegar	1	"			

This was a very satisfactory list. We had a few extras such as Worcestershire Sauce, ketchup, etc., which we gathered by cutting something else out. One month we might need no spices or only half rations of some other article. All men do not eat alike and all cooks do not use supplies alike. One would run out of milk while another would run out of lard or butter. Five pounds of fruit per man are needed, and I prefer five kinds (calling raisins a fruit). It will take about fifteen to twenty pounds of canned and after the first week men will tire of the canned nearly as much as of the old plan of plain dried apples. The cost of the above was at that time not far from ten dollars per month at that place. This includes only cost of goods. Company shipped them from Chicago to end of track, from whence they were brought by team.

In the Rocky Mountains, the past season, the following was the ration list supplied by the company :

RATIONS FOR ONE MAN THIRTY DAYS.

Flour	30	pounds.	Mustard	1½	ounces.
Fresh beef	25	"	Ginger	1	"
Ham	10	"	Allspice	1	"
Bacon	3	"	Cloves	1	"
Potatoes	35	"	Cinnamon	1	"
Oat meal	4½	"	Lemon extract	2	"
Corn meal	2	"	Vanilla "	2	"
Navy beans	3	"	Pickles	½	gallon.
Sugar	9	"	Cond. milk	3	pounds.
Coffee	3	"	Candles	3½	"
Lard	3	"	Soap	3	1-lb. bars.
Butter	4	"	Matches	3	boxes.
Evap. apples	2½	"	Vinegar	1	gallon.
" peaches	2½	"	Syrup	1	"
Tea	½	"	Soda (baking)	1-6	pound.
Salt	2½	"	Yeast cakes	1-16	"
Corn starch	½	"	Baking powder	1	"
Rice	2	"	Tomatoes	4	1-lb. cans.
Pepper	2	ounces.	Corn	4	" "

This list would have been improved by substituting five kinds of fruit for two, and by furnishing half the amount of canned corn and an equal amount of canned peas. In our party the allowances of soap, candles and vinegar were excessive, and butter, lard and milk too small. The potatoes took a great deal of milk. I have given these lists as guides. You will find that the meat and flour rations of the United States need to be closely followed. And in all matters of luxury, such as fruits, which are as a relish after the solids are disposed of, you will

find that a variety is what you need. Some of you may recall a detestable boarding house, where each dinner brought you a piece of dried apple-pie and each supper brought you a dish of stewed prunes. Does not your stomach recoil even now at the monotony of it?

Should you have to keep supplies for animals in addition to men it is a safe rule to calculate on 18 pounds of grain and 14 to 30 pounds of hay for each horse or mule. The different quantities of hay are according to quality. I would say 14 pounds of hay grown by irrigation in a rainless region, 22 pounds of cultivated timothy and red top and 30 pounds of native. Much of the latter is wasted. Hay raised in the rainless region is never injured by rain or dew and contains much more nutriment than when it is more or less bleached. Three burros (jacks) or pack ponies are equal to one horse or mule.*

One of the most unjust plans where a road has work in widely separated localities is the system of "cash rations" once in vogue on the Union Pacific Railway, where no difference was made in allowance between Nebraska and Kansas work where everything was cheap and the work in Colorado and Wyoming, where things cost two or three times as much. While a party could live well in the first-named region, in the latter it would barely give subsistence. And this difference in cost of living is too often lost sight of on roads where men are required to board themselves. Wages which are good in one region are very slim in another.

But, perhaps, in a profession like ours, where positions are of such a transient nature, and where there is such a lamentable disposition among so many to take what can be secured, it is useless to hope for any remedy of evils, and we must continue to make the best of circumstances, and the chief aim of many will still be to get out of the profession as soon as possible. I am fain to believe that much of this unjust treatment from our superiors is due to a lack of knowledge of conditions under which we labor. It is for this reason that I write this, knowing from experience that the last two lists are *good* wholesome living; fare on which men can work and be cheerful. Knowing needed quantities, cost can be figured by prices for that region.

DISCUSSION.

By H. W. Parkhurst.

The suggestion is made indirectly that estimates should be made somewhat in accordance with the actual expense on the work, classifying so as to cover this expense.

It may be of interest to the Society to know about a piece of railroad work which the writer let with the stipulation that the contractors might take their option, either to be paid by the engineer's estimates, or to demand ten per cent. above the cost of the work. The railroad lay along the bank of the Mississippi River, and its construction required moving a

* If you are not familiar with the "burro" or "Rocky Mountain Elevator," and wish to make his acquaintance you may find a charming description of him on his native heath in a little volume of "Letters from Colorado," by Mrs. H. L. Wason, who is evidently acquainted with him on his native ground. He is a Mexican jack and is indispensable in the mountains, where he carries everything from the school-ma'am and her "Saratoga" to the peregrinating saloon.

great deal of material which would fall under no one of the ordinary classifications, consisting largely of débris from the bluffs, broken stone, decomposed shale, clay, earth, gravel, and rock in all conceivable proportions. The need for an early completion of the work led to the adoption of so unwise a method of letting the contract.

The possibility of the "ten per cent." alternative being selected made it necessary to keep a force account. This was carefully done. The wages of men and teams were agreed upon, and were not to be changed without the engineer's consent, and on due notification. Timekeepers kept a daily account of the forces at work, returning this to the chief engineer's office, where the cost of each piece of work was figured up. All sub-contracts were filed in the chief engineer's office, and the cost of such work was also figured up monthly. The subdivision engineers made monthly returns to the chief engineer of quantities of work done, classifying it according to the specifications.

Each month, therefore, it was possible to determine what the probability was that the contractors would accept the estimates or elect to ask for the one hundred and ten per cent. They chose the latter alternative, although by our account the estimates exceed the amount so calculated on our time returns, and a lawsuit followed, whose end was lost sight of in the complications ensuing on the failure and flight of one of the contractors.

It is, perhaps, hardly necessary to point the moral never to let such a contract: but it is to be remarked that it may, perhaps, be an unwise thing for an engineer to let his judgment on classification be warped by any consideration of the cost of the work. As a matter of information, to know what work costs, and to govern in estimating future work, it may be wise to keep a force account, but not to determine how to classify work in progress.

The engineers' plain duty is to interpret the specifications fairly; but it is no measure of fairness to pay a lazy or injudicious contractor a liberal percentage above the cost of a badly managed contract.

By John W. Weston.

It appears to me that the commissariat appendix to the paper has diverted attention from the author's remedy for the frequent troubles arising from the classification of materials in railroad work. I can endorse the author's suggestions if the engineer himself is preparing in the future to take up the "contractor's" business, but I cannot see how it is possible to reach so close an estimate of the cost of a piece of work as to decide the profits to be allowed the contractor in the event of a dispute. And it must be conceded that it is the contractor's business what profit he makes and not the engineer's. It seems to me that without a certain amount of underhand work it is doubtful whether any contractor would not, and in a certain sense, rightfully, too, place every obstacle in the way of such a close scrutiny without some prearranged plan of action. Such a method would certainly be impracticable in a large manufacturing contract.

I have regretfully observed that very many of our engineers, overcome by zeal for the interests they serve, depart quite seriously from the line

of strict impartiality which is an attribute of our profession, and are guilty of unfair discrimination.

In my opinion the remedy should lie in certain contingency clauses in the specifications, which might in the event of dispute bring the engineer and contractor together to fairly measure and price the work.

By Benezette Williams.

It is safe to say that the divergence of opinion displayed by Mr. Van Auken's paper, and the discussion of the same by Messrs. Parkhurst and Weston with regard to methods which should be pursued in making classification in doubtful cases, is not as great as would be betrayed by an independent application of each gentleman's judgment to any particular case of the kind named.

This assertion is based upon the assumption that they are equally honest and intelligent, and that one has had fully as broad an experience as another in railroad work. If I am right, this condition of affairs implies a great deal more than engineers realize or are generally willing to admit regarding themselves, and the dual relation which they sustain to their employer and the contractor whose destiny they hold in their hands.

In addition to clauses defining the different classes of material, it is almost universal for a railroad contract to provide in the strongest language that the combined vocabulary of the lawyer and engineer is capable of furnishing, that the engineer's decision, not only in matters of classification but upon every possible question that can arise, is to be final and binding upon the contractor.

Take such a contract as this on work where it is admittedly difficult to determine the class to which material should belong, and the engineer becomes fully as important a factor as any judge upon the bench. Are engineers generally fitted by their training, and the relations they sustain to the parties in interest, to properly discharge such a trust? As to training, a part of them are, but a larger part are not. In their relations to the interested parties none of them are.

Let us suppose a case with a contract such as has been described, in which a part of the material being dealt with clearly belongs to a class, the price for which is greater than the cost of excavating it. Suppose the engineer to be, what he usually is, a subordinate to a higher official, who from the financial stringency of his company, or other reason, gives orders to have things "cut to the quick," will not the temptation be great—if Mr. Van Auken's suggestions relative to a force account be followed—to classify by a percentage so as to make the allowance equal the cost, on this particular part of the work, without regard to the fact that the contractor is losing money on another part, perhaps under a legitimate classification? Under such conditions we need not be surprised to find rock being classified as loose rock and loose rock as earth on the basis of the force account. Or suppose the engineer has made a preliminary estimate of the cost of the work upon which the road has been financed, that is found to be much too low, the temptation to shield himself from censure and his company from loss may be found too great to be withstood.

But it will be said that this is dishonest and no reputable engineer would engage in such business. True, it is dishonest, but all business is done upon the supposition that reputable men of any class may sometime do dishonest and unjust things under sufficient pressure. It is a recognized principle of legal morality that no judge or arbiter shall act in a case requiring absolute judicial fairness in which he is interested directly or indirectly. But engineers are continually placing themselves, or allowing themselves to be placed, in situations where not unfrequently hundreds of thousands of dollars depend upon their decision, without the slightest compunctions, notwithstanding they are dependent for their living and advancement wholly upon but one party to the case, and hence cannot be disinterested, or at least cannot maintain a disinterested position. Such trusts are accepted not only with an obligation to but one party in interest, but with an irremovable bias against the other party. Not against the individual, perhaps, but against the class to which he belongs. It is traditional with engineers that contractors are all liars and are only looking for a chance to cheat somebody. In addition to this they enter upon their work without any proper appreciation of the interests involved and without an adequate knowledge or experience for the work in hand.

In other words they are *particeps criminis* to contracts which give them the highest judicial powers, and then accept the position of judge with all their hopes of preferment and livelihood dependent upon one party to the contract.

But the most unique feature of this proceeding is that they should be able to do it with a conscience devoid of offense, and with the most indelible conviction that they are a whole generation of "Daniels" sent to protect innocent and confiding railroad corporations from the rapacity of designing and dishodest contractors.

The facts are that the methods pursued in letting and executing contracts for railroad, and other work, is wrong, and that engineers have in their weakness become parties to a dishonest system which no amount of contention over details of classification can ever make right.

They consent to work under a code of professional morality, that while scarcely allowing them to accept ordinary courtesies from one party to a contract in which they are made final arbiters, will permit them with impugnity to become the paid servant to the other party. We are all so used to this that we are incapable of appreciating its enormity. Under such a system what wonder if a contractor persuades himself that since the party of the second part can have an obedient servant for a judge, that it is necessary for him, the party of the first part, to buy justice; and what wonder if sometimes he gets more than justice by purchase. In a last analysis of the ethics of such a case an impartial mind must admit that there is no difference between the parties of the first part and second part, and that the poor dupe of an engineer is fully as likely to display judicial mindedness when receiving pay from both sides as when receiving it from only one.

It is perfectly feasible to do away with such an immoral and unjust system, and engineers should have the manhood to demand that it be done away with, and to refuse to work as hired judges any longer.

Contractors, for their own protection, should combine and refuse to take work under contracts which places them in a position of either accepting the decision of one man or a resort to the courts. Both contractors and engineers who believe in honest methods should work together for this end.

Though the manner in which an architect conducts his business places him in a far more independent relation to both the contractor and the owner than the engineer sustains to his employer, it has been found necessary to provide methods of reversing the architect's decisions relative to the cost and quality of work without an appeal to the courts.

The American Institution of Architects, the Western Association of Architects and the National Association of Builders have lately agreed upon a form for uniform contracts to be used in building operations, which provides that "Should any alterations be required in the work shown or described by the drawings or specifications, a fair and reasonable valuation of the work added or omitted shall be made by the architect, and the sum herein agreed to be paid for the work according to the original specification shall be increased or diminished as the case may be. In case such valuation is not agreed to, the contractor shall proceed with the alteration, upon the written order of the architect, and the valuation of the work added or omitted shall be referred to three arbitrators (no one of whom shall have been personally connected with the work to which these presents refer), to be appointed as follows: one by each of the parties to this contract, and the third by the two thus chosen; the decision of any two of whom shall be final and binding, and each of the parties hereto shall pay one-half of the expense of such reference.

Could engineers descend from their lofty plane long enough to confer with contractors they would perhaps discover that because a man may be a contractor he is not necessarily more dishonest, and is often more competent than the engineer, that he is amenable to reason and only desires to have some way of settling differences of opinion and judgment other than by the law.

I have dwelt upon the character of contracts, and the manner of executing them, rather than upon the method of making classification because it is the system which is at the root of much of the difficulty. But taking things as they are it is evident from this discussion that there is no harmony of methods, that no contractor can rely upon getting the same classification from two different men. Where so much latitude exists then surely some easy way should be provided of having a disputed case adjusted in which the contractor's voice can be heard. As it now is, in a case involving important classification, the character of the engineer is of far greater importance than the character of the contract.

HENRY FRANCIS WALLING.

MEMOIR BY C. W. FOLSOM, F. O. WHITNEY AND E. L. BROWN, COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read November 21, 1888.]

The future historian of the progress of our profession in this country, especially in the department of map-making, cannot omit the name of Professor Henry F. Walling.

So far as your Committee can learn from Mr. Walling's business records, between the years 1848 and 1888 he prepared and published, either alone or with others, maps of no less than 20 States and Provinces, 280 counties, and over 100 cities, towns and special localities.

These were commercial maps, and subject to the defects of such. The public is rarely ready, especially in such a new country as ours, to pay *individually* for that high degree of scientific accuracy which a national or state undertaking only can secure, and which no one appreciated or understood better than Mr. Walling himself. But they were fully up to the requirements of the times when they were issued, and to the condition and resources of the country represented.

Map-making follows the universal law of evolution—first, the grain, and then the ear, and then the full corn in the ear.

For a full scientific triumph like the Ordnance Maps of Great Britain the public mind has to be trained through long courses of years by less exact and costly representations, each in turn serving the needs of its generation, and paving the way for the next step onward.

Henry Francis Walling was born at Burrillville, Rhode Island, June 11, 1825. As might be expected, his immediate ancestors, though plain and unpretentious people, showed the traits of industry and integrity, combined with gentleness and amiability, which distinguished their descendant. His father for many years carried on a mercantile business in Providence, and his grandmother was a member of the Society of Friends.

Henry was educated at the public schools of Providence, where his teachers remember him as a sober, thoughtful pupil, with a mind constantly at work, and excelling without effort, especially in mathematics. He was disposed to investigate for himself, rather than to blindly accept the solutions of others.

He then fitted himself for a university education at the school of Thomas C. Hartshorn, and at Lyon & Frieze's, but did not enter college; having married in May, 1847, Miss Maria Fowler Wheeler, he being not quite 22 years old, and she being 16. Their first child, a son, born in August, 1848, lived to be eighteen years old, and was in his second year at Yale College when he died very suddenly. He was a very promising young man, the pride and hope of his parents, and from this loss Mr. Walling never fully recovered. Two daughters survive their father, the eldest of whom is married and lives in Rhode Island.

This early marriage, which prevented Mr. Walling from carrying out his plans for a more finished education, led him at once to take an

active part in the business of life. He had been assistant librarian of the Providence Athenæum, and had taught an evening drawing school with marked success.

He soon became a partner with the late Samuel Barrett Cushing, an engineer of great local repute, and early began his series of maps (afterwards constantly followed up) with that of the town of Northbridge, Massachusetts.

In 1858 he left Providence and went to New York, where he established a map-making business in all its details. For this he employed surveyors whose work he carefully revised, and had the maps engraved under his own personal supervision. This work he carried on very successfully and with great financial comfort until 1861, when the civil war broke out and ruined the business.

One of your Committee recollects very well a talk with him about this matter some years ago. Mr. Walling said that the immense rise in all materials entering into map-making—the cotton, rolls, boards, and glue even—consequent upon "war prices," was enough to make it impossible to manufacture unless at a loss. Add to this that the demand almost entirely fell off, as Mr. Walling's maps unfortunately were not of those States that became the battle-fields of the war; and it was a foregone conclusion that the business must stop.

In March, 1868, Mr. Walling accepted the chair of Civil and Topographical Engineering in the Pardee Scientific School of Lafayette College, at Easton, Pa., where he remained three years, when he was persuaded by his former business associates to come to Boston and resume the work of map-making, which he never entirely gave up again. As time went on, he took a position on the U. S. Geological Survey.

For many years it was the desire of his life to bring out an accurate and extensive map of Massachusetts; and when he found it could not be accomplished by private enterprise, he joined with great zeal and interest in the labors for the production of the one that is now forthcoming under the joint care of the State and of the United States Geological Survey. He was engaged at the time of his death in locating the town boundaries upon this map, and connecting them with the triangulation. He died very suddenly, with only a brief illness, of heart disease: and after his eyes had closed to their earthly labors, his computing book still lay open upon the table where he had used it a few hours before.

Professor Walling was an honest, sincere, upright man, and an earnest seeker after the truth: a man of singular reserve, and rare modesty, never obtruding his private affairs or opinions upon others; but a man of decided convictions, and disposed to go to the root of matters, rather than to rely on custom or tradition. His *pleasure and relaxation* lay in his studies and speculations on physical theories, such as of force, attraction, the "ether," the atomic theory, etc., etc. He contributed many papers on many subjects to the meetings or journals of the various scientific societies to which he belonged. He was an active and respected member of the American Society of Civil Engineers, to which he contributed several valuable papers upon topographical surveying, such as "Co-ordinate Surveying," "Cadastral Maps in Ohio," "Co-operation between National and State Governments in Topographical Surveying."

At the annual meeting held in New York, November 7, 1877, Professor Walling presented a form of memorial to Congress in reference to extending the triangulations of the United States coast survey. The memorial was afterward submitted by letter ballot to the members of the society, and adopted April 3, 1878. Two copies were engrossed and signed by the President and Secretary and forwarded, one to the Senate and one to the House of Representatives of the United States Congress.

Professor Walling served as a member of the Local Committee when the annual convention was held in Boston, June 18, 1878, and in Washington, May 16, 1882.

We all remember Mr. Walling's deep interest in the success of the Boston Society of Civil Engineers, although but one of his papers, that on "Topographic Survey of States," appears in our published transactions.

Our members will well recollect the amusing jeu-d'-esprit in verse which he read at our annual dinner two years ago, "A Study in Prophetic Engineering," in which he took a humorous view of the possible future of the profession in 1986, describing the "graceful soaring air-yachts," each man's "private electric railway" from his own back yard, the "tunnel under Behring Straits," the water supplied from the Great Lakes to the great cities, a "photophonic signal code from the moon," and, best of all, his remedy for the blockades on street railroads in great cities by having Stewart's, Wanamaker's and Jordan & Marsh's great stores mounted on wheels and passing along in front of each lady's door, the purchaser boarding the sales-car in front of her own residence, and getting out at the same place, or at a friend's. after concluding her shopping.

Mr. Walling had the love and respect of all who knew him; hospitable and sociable at his own home, and eminently companionable among his scientific associates, he was notably kind and patient with his assistants and employés. He never made an enemy, and left every one who knew him a friend.

REPORT ON CIVIL ENGINEERING AND SURVEYING PROGRESS.

By a Committee of the Civil Engineers' Club of Cleveland.
[Read October 9, 1888.]

The Committee on Civil Engineering and Surveying begs to submit the following report on Civil Engineering progress during the last year:

Your Committee has in several cases endeavored to give in its own language and condensed form descriptions of great works which are elsewhere treated in a manner too voluminous for the busy engineer. In other instances it has borrowed from various sources, with poetic license of omission and addition.

The report embraces concise accounts of a few of the more notable works proposed, completed or in process of cosntruction, both in this country and Europe.

THE TRANS-CASPIAN RAILROAD.

One of the important engineering events in the old world was the

completion during the past summer of the Trans-Caspian Railroad from the Caspian Sea to the historical city of Samarkand, the capital of Bokhara. The work was first begun in 1881 by the Russian Government, who built 144 miles of railroad for military purposes from Mikhailoosk on the Caspian Sea to Kizel Arvat, under Gen. Annenkoff. The portion just completed, also under his direction, commenced at Kirzel Arvat and was built to Samarkand by way of Merv, a distance of 736 miles. The easterly terminus was also extended 14 miles easterly to the port of Ozoun Ada, on account of greater depth of harbor there.

The railroad crosses the Turkestan Plain, practically a sandy desert, there being stretches of 100 miles entirely without water, and only 3 streams of importance cross the route throughout its length. The work presented greater natural obstacles than the building of any one of our Pacific roads, but not such great engineering difficulties. The grading was mostly done by native workmen who received about 10 cents a day. They were allowed to carry sand for the road in the skirts of their scanty dresses. It was thought best to allow them to use their own methods of work and not put tools into their hands, which they would not know how to use. As many as 30,000 laborers were employed at one time. Hardy plants had to be cultivated along the road to prevent the moving sands from burying it. All ties and wood were brought from Russia, also steel rails, which cost $80 per ton, and were furnished by the Russian Government; weight 64 pounds per yard. The longest bridge is over the Amon Darid River, length 13,776 feet, but only 6,225 feet in bed of river. It is a pile bridge, cost $160,000. The 750 miles of road were built in 28 months; total cost, $19,553,600, or at the rate of $25,936 per mile. Russian rolling stock is used, consisting of 1,400 cars, and 80 locomotives, burning petroleum. The road is now being extended to Taschkend. A yet grander railroad is now proposed by Russia, the Trans-Siberian, to reach from the Ural to Vladivostok, on the Sea of Japan, 3,720 miles, and to connect same with Trans Caspian Railroad by line from Omsk to Taschkend, about 620 miles. A road will doubtless be built from Orensburg to Taschkend, giving all rail route from St. Petersburgh to Samarkand. At present Samarkand is brought to within 6 days journey of Moscow.

THE FORTH BRIDGE.

The building of the bridge across the Frith of Forth in Scotland is undoubtedly one of the greatest engineering feats ever attempted. The following statements will give some idea of its magnitude: The bridge is about 1⅝ miles long, and has a clear headway of 150 feet to allow the passage of the largest ships. It consists mainly of three enormous double cantilevers, two 1,505 feet and one 1,620 feet in length. The effective depth of truss over the piers is 330 feet, and at the ends 35 feet. These cantilevers rest on gigantic masonry piers, each pier consists of a group of four columns, each column being 49 feet in diameter at the top and 36 feet high, which rest either on the solid rock or on concrete carried down in most cases by means of caissons of maximum diameter of 70 feet, to solid rock or boulder clay. The middle pier rests on Inchgarvie, a small island fortunately dividing the deep water space into two channels of nearly equal width. The total length of the bridge is 8,296

feet. There are two spans of 1,710 feet, two of 680 feet, fifteen of 168 feet, four of 57 feet, and three of 25 feet, the latter being masonry arches. The extreme height of structure is 361 feet above, and the extreme depth of foundations 91 feet below high water mark. The centre portions of the two 1,710 feet spans on each side of Inchgarvie are formed by two lattice girders 350 feet in length, 50 feet deep in the center, and 37 feet deep at the ends. There will be about 53,000 of steel in the superstructure, and about 140,000 cubic yards of masonry and concrete in foundations and piers. The engineers say there seems to be no reason now why the bridge should not be finished by October 1, 1889.

THE CORINTH CANAL.

One of the oldest engineering projects in the world is now gradually approaching completion, and the work will probably be finished the coming year. This is the canal across the Isthmus of Corinth, in Greece. It was first planned some twenty-five hundred years ago, and work was actually begun under the Emperor Nero, but discontinued at his death. The present work was undertaken four years ago by the French. When completed it will be about 4 miles long. It is 8 metres deep, enough for the largest vessels now navigating the adjacent seas. It was expected to open it this year, but the engineers thought best to wait until the completion of some masonry retaining walls on a section about 1¾ miles long, where the excavation is through a light, sand soil, not fitted for permanent banks. The walls will prevent frequent obstruction and dredging. The cost of the canal will be about nine million dollars, being about four million more than the estimate. The work has been done under French engineers. It is considered very doubtful if the tolls that can be collected will pay interest on the investment.

THE EIFFEL TOWER, PARIS.

What will be one of the most remarkable structures of the present age is now building in Paris for the exposition of next year. It is known as the Eiffel Tower from the name of the engineer designing it. It is to be a structure of iron 300 metres or 984 feet high, and will be by far the highest structure in the world, being nearly one and eight-tenths times the height of the present highest structure, the Washington Monument. The tower stands upon four legs on a base of 100 metres square. Each leg consists of 4 columns; each column rests upon a large casting supported by hydraulic jacks, by means of which the columns have been raised more or less and plate-iron packing put under them, and thus the tower has been accurately plumbed to a perpendicular line, and any future slight settlement can be readily adjusted. The weight of the iron work is seven million kilogrammes, 7,767 American tons. Each column requires a force of 425 tons to lift it, and each jack has a power of 600 tons. The columns are made of plates and angles decreasing in size and area from bottom to top. The columns are inclined at quite a large angle with the perpendicular for about two-fifths of the height, where the outline gradually assumes a more perpendicular shape, the profile of the tower in elevation resembling a flat ellipse. The columns are connected by braces formed of angles and riveted lattice bars. The pieces of the columns are connected by splice plates, to which the braces are riveted. The pieces of the columns are short, from 3 to 4 metres long, no

piece being of great weight, say from 7 to 10 tons. The tower would have a better effect to the eye if the base had not been made so broad, which was not necessary from an engineering stand point. As it is, the effect is of over strain in the legs by reason of their great obliquity. Ascent is to be made by means of two elevators or lifts. The lower system extend, from the ground to the second galleries, about one-half way up the tower, and will be put in by an American firm—the Otis Bros. & Co., who are now engaged on the cylinders at their works at Yonkers, N. Y. From the second floor to the top the elevator will be a French one, known as the " Edoux" ram-lift system. It is stated that M. Eiffel could not obtain in France the proper elevators for the lower lift, and was compelled to come to this country for them. This has caused some feeling against him in France, and he has been criticised into by the papers for applying to foreigners, but he would not have done so could he have avoided it. The tower is expected to pay a large revenue from sightseers, and from restaraunts, etc., in the different galleries, of which there are three.

If it proves a financial success, it will, undoubtedly, be imitated in many of the large cities of the world.

THE PANAMA CANAL.

So much has been written lately, both in the technical journals and in the newspapers about this gigantic undertaking and the chances of its ultimate success or failure, that the public has become pretty well informed in regard to it, and your Committee will not, therefore attempt any description of the work, but will simply remark that, despite the enthusiastic and inspiring declarations of De Lesseps and his French admirers and supporters, many of the best informed engineers are of the opinion that the work will never be finished by the present company, and probably not at all. The failure of the enterprise would prove one of the greatest financial disasters in the world's history, and bring ruin to thousands of investors in the stock and bonds of the company. It must be confessed that the present outlook for the completion of the canal is far from bright. The company has already expended over two hundred million dollars, and only about one-fifth of the work for a sea level canal has been accomplished. Even with the substitution of temporary locks, as now proposed, it is doubtful if the work can be finished inside of five years. There are to be ten of these locks, to cost a million dollars each. It seems that the latest scheme of the company to replenish its finances has not proved much of a success. Of 140 million dollars worth of lottery bonds offered only 56 million dollars worth were taken by the public, and of this amount only about 12 million dollars are available for the prosecution of the work, the other 44 millions being required for the purchase of Government securities guaranteeing the loan and for payment of interest due. The fixed interest charges are said to be about 20 millions per annum. In face of these facts it is hard to see how the canal can ever be a financial success, even if it should be finished as now proposed. However, all will unite in the hope that the worst fears may not be realized, and that the greatest engineering enterprise of the age may not terminate in utter and disastrous failure.

One of the great projects now under contemplation is the

LAKES AND GULF WATERWAY.

This is to be a free national waterway wide and deep enough for the largest river steamers, and for naval vessels in time of war, and which will afford a large and steady supply of water to the Illinois and Mississippi rivers.

Route.—Of two proposed routes, the following will probably be first constructed :

From Lake Michigan, by way of Chicago River, with branch uniting at west fork of the south branch, near city limits, thence by artificial channel southwesterly in the bed of Mud Lake to the Desplaines River, at Summit, eight miles: thence southerly, by channel in the rock bed of the Desplaines, to Joliet Lake, 28 miles; thence by slackwater locks and dams and channel improvement in the bed of the Illinois and Desplaines (64 miles), to La Salle, the present head of navigation on the Illinois: thence to the Mississippi and Gulf.

Contour.—Chicago to Romeo, 27 miles, surface of ground is about 6 feet above mean level of Lake Michigan.

Romeo to Lake Joliet, 10 miles, there is a descent of 77 feet below lake level.

Lake Joliet to La Salle, 60 miles, there is a fall of 70 feet.

Total Distance.—Lake Michigan to La Salle, 100 miles: total fall—Chicago, to La Salle, $146\frac{6}{10}$ feet; La Salle to mouth Illinois, fall of 27 feet.

Size of Waterway.—Chicago to Lake Joliet channel is proposed to be 160 feet wide and 22 feet deep; current, 2 miles per hour: capacity, 600,000 cubic feet per minute; Lake Joliet to La Salle, slackwater locks, dams and improvements to bed channel, 300 to 600 feet wide not less than 14 feet depth; La Salle to Mississippi, 10 feet depth on bars at low water, ultimately 14 feet.

Effect on Illinois and Miss. Rivers.—Claimed that it will add vigor and improve low water stages (estimated 1 foot between St. Louis and Cairo, 6 inches below Cairo).

Water Power.—It will create 100.000 horse between Lockport and La Salle, making this the great manufacturing centre of the country, on account of its accessibility north and south by navigable water and proximity to the great distributing point of the Northwest. The capacity of the proposed channel, as a sewage outlet, will, it is claimed, be ample for a population of 2,500.000.

Legislative Action.—It is proposed that Chicago shall pay the cost of taking care of the sewage, leaving to the United States the expense of suiting channel to wants of navigation.

Geological Formation.—It is claimed that before the last glacial period, the upper lakes, Michigan, Huron and Superior, discharged 20 feet in depth across the Chicago divide, which with the exception of alluvial deposits of limited extent is but 6 feet above the mean level of Lake Michigan.

Cost—Estimated.

Chicago to Joliet	$17,000,000	to	$21,000,000
Diversion of flood waters north of city	2,500,000	to	2,800,000
Channel Lake Calumet to the Sag	2,500,000	to	3,000,000
Other related works	1,100,000	to	1,150,000

These channels are designed to carry full quantity of water under most unfavorable conditions, to be navigable to Lockport and to conduct the water to Lake Joliet.

Claims.—The production of a magnificent waterway suitable to boats of 2,000 tons burden, with available water power twice that of the Miss. at Minneapolis.

This project has received the consideration of a Committee on Main Drainage, Chicago; commission appointed by Illinois Legislature, committee appointed by Peoria Convention, 1887, and representing the States of Illinois, Iowa, Missouri, Tennessee, California and Maryland, to present the Lakes and Gulf Waterway project to Congress.

THE POUGHKEEPSIE BRIDGE.

The great bridge across the Hudson River at Poughkeepsie was practically completed on August 30 last by the connection of the last river span. The principal part of the bridge if on the cantilever principle. The total length, including approaches, is 6,777 feet. There are five river spans and four river piers. The centre span is 546 feet and the two shore spans of 548 feet each. There are two intermediate spans of 525 feet each, being parallel chord trusses connecting the ends of the cantilevers. The bridge is a deck bridge for railroad purposes, and the rails are 212 feet above high water. The river is about 2,600 feet wide, with from 50 to 60 feet depth of water. The piers are of iron and rest on masonry foundations which extend to 30 feet above high water. The Union Bridge Company are the engineers and contractors. They began work in 1886 and the bridge will undoubtedly be open to travel within a few months, there being still a considerable amount of work to be done upon the approaches.

THE CENTRAL VIADUCT, CLEVELAND, OHIO.

What is known as the Central Viaduct of this city which has been under construction for the last two and a half years, will undoubtedly be ready to open up to public use in December next. The following facts and figures will give a general idea of the structure.

The viaduct consists of two portions, one across the Cuyahoga River valley and the other across the valley of Walworth Run. Each consists of a series of iron bridges of various lengths, supported upon iron piers resting on masonry pedestals. There are masonry abutments at the ends, and a drawbridge over the river resting on masonry piers.

The following are the dimensions of the

Cuyahoga Valley Portion.

Length of floor of viaduct	2,839	feet.
Height of roadway at river above ordinary stage of water	101	"
Height of roadway above tracks on Nickel Plate viaduct	33	"
Length of draw span	236½	"
Width of roadway	40	"
Width of sidewalks	8	"
Length of paved approach at east end	622	"

Walworth Run Portion.

Length of floor of viaduct	1,092	feet.
Height of roadway above N. Y. C. & St. L. R. R. tracks	35	"
Height of roadway above Scranton avenue	76½	"
Height of roadway above C., C., C. & I. R. R. tracks	68½	"
Width of roadway	40	"
Width of sidewalks	8	"
Length of paved approach to east end	873	"

Total Quantities in Both Portions.

Masonry	16,792 cubic yards.
Concrete	4,584 "
Foundation timber	969,440 feet, B. M.
Foundation piles	64,442 lineal feet.
Iron in foundations, about	76 tons.
Iron in superstructure	4,850 "
Lumber in flooring	817,000 feet, B. M.
Lumber in paving blocks	753,000 "
Weight of draw span, about	554 tons.
Length from Hill street to Abbey street	5,426 feet.
Length of iron viaducts	3,931 "

The total cost of the whole viaduct, including right of way, will be about $900,000. Being for substructure about $247,500, and for iron superstructure about $325,000; the balance, $327,500 being for right of way and all other expenses, including paving of approaches, planking and paving bridges, stairways, lighting, etc. The total amount allowed by law for the viaduct was one million dollars.

MISCELLANEOUS ENGINEERING NOTES.

Steel Rails.

Steel rails weighing 90 pounds per yard have recently been rolled by the Bethlehem Iron Company, of Bethlehem, Pa., for use on the Reading Railroad. They are said to be the heaviest steel rails ever rolled in this country.

Locomotive Building.

The Pennsylvania Railroad Company has succeeded in erecting a 55-ton locomotive complete in 16 hours and 55 minutes. Work was begun at 7 A. M. June 18th last, and in the time mentioned the engine was turned out ready for use, thus breaking the best previous record, 24 hours, held by the Baldwin Locomotive Works. Of course, all due preparation had been made beforehand, but the feat is nevertheless a remarkable one.

A Paper Chimney.

A novelty in chimney shafts is reported from Breslau. A shaft 54 feet high has recently been erected there constructed entirely of solid blocks of paper cemented together. It is claimed that the shaft is both fire and lightning-proof.

Hardening Wood.

According to *Iron*, a newly invented process of hardening wood is being turned to practical account by the Germans. The process consists in steeping the wood in a bath of caustic alkali for two or three days at a temperature of about 180 degrees Fahrenheit, after which it remains for two or three days in a bath of hydrosulphate of calcium. The process is completed by a bath of acetate of lead at a temperature of about 110 degrees Fahrenheit. Wood thus treated has many of the properties of metal and is susceptible of a very high polish, but is lighter and unaffected by moisture.

Ballast Spreader.

The Chicago, Burlington & Quincy Railroad is said to be experimenting with the Rodgers "ballast car and spreader" in its freight yard at Hawthorne. This is a car very much like an ordinary hopper car, but has a capacity of 50,000 pounds. The hopper runs the length of the car, and extends to within 1 foot of the track, and it is opened, and the fall of the stone controlled by levers. The spreader is a steel plow, fastened under the body of a flat car and reaching below and on both sides of the

rails. The car travels at the rate of three miles per hour, and in the trial 20 tons of ballast were spread along a new track in about one minute.

Surveying and Local Notes.

The tendency of our best surveyors is still in the direction of greater precision in the measurement of angles and distances. The steel tape has almost entirely superseded the chain, and surveyors are now paying attention to the elements of tension and temperature in the measurement of distances who formerly regarded these matters as useless refinement. There is a chance for some instrument maker to make a hit by devising a neat and practicable handle for a steel tape, containing a thermometer and spring balance, that will meet the wants of practice. The trouble with those now made is that they are too cumbersome and ininterfere with the use of the tape in measuring.

In this connection it may be mentioned that in the construction of the Central Viaduct from Jennings avenue to the East Side, a distance of about 2,800 feet, including a triangulation across the river, the measurement of the engineers laying out the work only differed ¼ inch from that of the original survey.

Among recent local surveys the location during the past summer of the proposed street in the valley of Walworth Run, from Scranton avenue to Gordon Avenue, may be mentioned. The length is 2.3 miles, and the survey is the first one made along the Run with the precision necessary for the appropriation of land. This survey and location is of importance as being the forerunner of the contemplated main sewer to be built in the street should the latter be opened up. Proceedings for the appropriation are now in progress in the City Council of Cleveland.

Mr. Varney reports that in giving levels for the Arcade Building, this city, he used two levels, one checking the other, and preventing any gross error in elevations being made, and also detecting and leading to correction of slight errors. He is now using a transit made by J. W. Holmes, in which the stadia wires are not set at the same focus as the ordinary cross wires, and thus any danger of mistaking one for the other is prevented. Respectfully submitted,

WALTER P. RICE,	
A. MORDECAI,	Com. on
J. D. VARNEY,	Civ. Eng.
JOHN L. CULLEY,	and Surv.
H. B. STRONG,	

DISCUSSION.

Mr. Whitelaw: Did any of the reports on the Hennepin Canal take into consideration the effect on the level of the water of the lakes?

Mr. Rice: There has been a discussion by the Chicago Club of the effect on the lake levels. The amount of water taken would only aggregate a depth of about $2\frac{1}{10}$ inches in the course of a year, and as the fluctuations due to rainfall and other causes are so much in excess of that, it would be of no practical significance. It would be difficult to detect that any water had been abstracted from the lake. During the flood

stages the first effort would be to replace the water taken away. The outlet has not sufficient capacity to discharge the flood waters at once.

Mr. Whitelaw: When the project was first considered seriously there was a good deal of discussion on the subject, and many engineers thought it would result in a permanent lowering of the lakes.

Mr. Varney: Will not the future needs of the canal demand a greater water flow?

Mr. Rice: It is claimed that the capacity of the proposed channel (600,-000 cubic feet per minute) is sufficient for a population of 2,500,000. I think the only place where proposed lake discharge would have any effect would be on the slope of the St. Clair River, especially the rapids, and that would be too small to take into serious account. The fluctuations due to rainfall would influence all the lakes. It seems useless to talk of the effect of the withdrawal of two and seven-tenth inches.

Mr. Mordecai: What is the area of the water going over the Falls of Niagara?

Mr. Rice: I do not know what is the discharge from the Niagara, the amount of water withdrawn by proposed canal would be about one-twentieth of the discharge from the Detroit River.

Mr. Varney: Is it claimed that the rainfall at any particular time has raised the level of the lakes two or three feet?

Mr. Rice: The annual rise is generally 12 to 16 inches in amount. The annual mean level of Lake Ontario in 1870 was $2\frac{8}{10}$ feet higher than in 1872. The variation between highest and lowest water known is six feet and some fraction. I think the highest stage was in 1838; it is the greatest of which we have any record, and is used as the plane of reference.

Mr. Baker: Was not that highest stage in 1838 when they tried to fix the base of level? There was a mark made by Colonel Whittlesey. The ordinary stage is about two feet below that.

Mr. Whitelaw: It came near it in 1877. Mr. Hubbard, of Detroit, in his book called "The Recollections of Half a Century," gives the fluctuations of the lakes and tries to account for them. His article on that subject was copied in the *Popular Science Monthly*. (Mr. Whitelaw makes diagram.) The first line in the sketch represents the periods of the maximum sun spots; the next, of the rainfall, next, of the atmospheric variations, and next, of the fluctuations of the lake surface. He reasons that there is a lag of some months between the maximum periods of sun spots, rainfall and maximum water level. He tries to show that the cause of high water is primarily maximum sun spots, which take precedence of the other phenomena.

Mr. Rawson: Have any fluctuations been calculated as due to tides?

Mr. Rice: They are very slight. I think about $\frac{1}{10}$ of a foot. It was only determined by a long series of observations. The tidal change at Chicago is given as having an amplitude of $1\frac{1}{2}$ inches for neap tide and 3 inches for spring tide.

Mr. Searles: The current number of *Engineering News* gives diagrams showing the stages of water in great lakes since 1859, the monthly variations, the annual average variations, and also a somewhat parallel profile showing the rainfall. The annual profile for the surface of the lakes is

very nearly parallel with the profile for the rainfall, while, of course, the monthly variations are much more irregular. The extreme variation amounts to about two feet, the lowest being in 1872, and the highest in 1886. The variations on Lake Ontario have much more amplitude.

Mr. Varney: Has any one noticed any temporary tides in the lake here? A few years ago I went with my wife and daughter to the foot of Wilson avenue, and they went down on the shore to a little peninsula apparently about two feet above the water. The water was nearly still at that time, but standing back on the bank, I noticed that it was rising, and within five minutes it was overflowing the peninsula, it rose in fact five feet within a few minutes. I am giving the figures from memory, but they are about correct.

Mr. Whitelaw: That was known here as the "tidal wave." It flooded some of the railroad tracks. It has been explained as due to a sudden passage of a very low barometer area over the lake, causing a sudden atmospheric pressure.

Mr. Varney: I observed a heavy black cloud in the distance.

Mr. Rice: There are certain limits in the fluctuations of lakes in which changes occur due to atmospheric pressure. They are generally slight in amount. I had the pleasure of making an investigation for the government with regard to the last wave. It rose eight or nine feet. The signal observer said that no disturbance was noted on his instruments. The barometer was the only instrument that went out of its ordinary course. The heavy cloud over the lake seems always to have been an accompaniment to the tidal wave. I have always had the idea that it was the force of impact added to the atmospheric pressure, and I was led to believe that it was something in the nature of a tornado. There was scarcely a breath of wind here, such slight breeze as there was shifted and came with the cloud. I went out on the ridge and found that there had been a severe wind there, and that we had been in a sort of atmospheric eddy. This happened about five years ago. The wave came up on the Lake Shore track. The piles were eight or nine feet above water, and a building was litted off the piles. There are quite a number of records of this wave, and Colonel Whittlesey mentions a number of others. I saw an account in a Detroit paper of a lake steamer meeting just such a wave.

Mr. Searles: According to the law of wave motion the crest is as high above the mean level as the trough is below it. It is understood that this measure of six feet is from the extreme low point of the wave to the extreme high point, so that the six-foot wave as measured would be only three feet above and three feet below the mean level—there would be only a three-foot variation from the surface of equllibrium.

Mr. Rice: Yet I found that the piles were eight feet above the water, and the building was lifted off the piles.

Mr. Rawson: That is correct. At the time we were building the bridge at Erie street. The men had left their tools there, and were ready to go down. When I got there the water lay in pools on the bank that I should have said was twelve feet above water. Loose railroad bars were actually rolled over on the tracks.

Mr. Searles: In reference to the Hennepin Canal, Mr. Rice's suggestion

in regard to flood water is ingenious. In times of low water we have difficulty in navigating the St. Clair River. Now, if in that low stage we have an outlet at Chicago, will not the St. Clair River suffer still more? At the extreme of low water the loss at Chicago may act seriously on navigation on the St. Clair River. It is only at times of extreme drought that any damage to navigation need be feared?

Mr. Baker: Will there not be a pollution of the canal from sewerage?

Mr. Rice: The people along the river have been complaining, but the explanations of the Chicago people appear to have overcome the difficulty, as they propose a sufficient dilution. The volume of water in the canal is 600,000 feet a minute.

Mr. Whitelaw: If the canal is going to improve the navigation of the Mississippi River so much it will injure the channels.

Mr. Rice: I think not.

Mr. Varney: Is the grade such that they can use them with locks?

Mr. Rice: As I understand it, there is to be an artificial channel about 36 miles long to Joliet Lake, after that 64 miles by slackwater, dams, and channel improvement.

Mr. Mordecai: I understood that there were to be locks as far as Lockport. I observe that the report did not notice the ship canal from Liverpool to Manchester.

Mr. Searles: I was struck by the figures of the Manchester canal. The contractor is using 150 locomotives, 1,500 flat cars, 70 steam shovels and 15,000 men on a canal 35 miles long—a wonderful concentration of engineering force.

CONDENSERS FOR STEAM ENGINES.

By J. H. Kinealy, Member of the Engineers' Club of St. Louis.

[Read December 5, 1888.]

During the last few years manufacturers have been paying a great deal of attention to the economy of steam and fuel, and have been trying to get as much work out of each pound of coal as possible. This is shown by the number of improved boilers and furnaces designed for complete and economical combustion of fuel that is in use, and by the fact that engines of the Corliss type and engines with automatic cut-offs are becoming more and more common.

But while manufacturers have been paying much attention to the improved engines, boilers and furnaces, they have almost entirely overlooked the condenser, a most beneficial and economical adjunct to an engine. Except at very large establishments, water-works, large mills and foundries in the East, condensers are not as much used on land as they might be.

Provided there is a good supply of water at hand there is no reason why a condenser should not be used with any engine, whether a high or low pressure engine.

Of the two kinds, the jet and the surface condenser, the jet condenser is more generally used on land; because it is simpler, is not so apt to get out of repair, and gives as good, if not better results than the other.

In the jet condenser the exhaust steam from the engine enters a chamber where it comes in contact with the condensing water, in the form of spray, by which it is condensed. This chamber, in which the condensation takes place, is the "condensing chamber." The condensed steam, together with the condensing water, is pumped out of the "condensing chamber" into the "hot well" by means of a pump called the "air pump." Part of the water in the hot well is pumped back into the boiler by the feed pump, and the remainder is allowed to run to waste.

The condensing water is sprayed when it enters the condensing chamber by means of a rose fixed on the end of the injection pipe, or by means of a perforated plate, called the "spattering plate," fixed inside of the condensing chamber.

The principal parts of a jet condenser are: the condensing chamber, the air pump and the hot well.

In the surface condenser the water for condensing the steam passes through a number of small copper or composition tubes, on the outside of which the steam to be condensed circulates. The steam coming in contact with the cold surface of the tubes is condensed and falls to the bottom of the condenser, from where it is pumped into the hot well.

The condensing water is either drawn or forced through the condenser tubes by a pump called the circulating pump.

The surface of the tubes that is in contact with the steam forms the condensing surface of the condenser. These tubes are always of very small diameter, and the metal of which they are made is as thin as is consistent with safety. Sometimes, instead of the steam circulating on the outside of the tubes, it passes through them and the condensing water circulates on the outside.

The principal parts of a surface condenser are:

The condensing surface, being the surface of a great number of very small tubes, the air pump, the circulating pump, and the hot well.

Jet condensers for land engines are generally provided with independent steam cylinders for working the air pump. Condensers of this class, of which there are several of different make upon the market, will pump their own water of condensation; but they ought not be expected to draw water more than about 12 or 15 feet, as there are a great number of joints about a condenser that are difficult to keep air tight, and the water flows into the condensing chamber against whatever pressure is there.

The great point in favor of the surface condensers is the fact that the steam, after being condensed, is returned to the boiler and used again without it coming in contact with the condensing water. The same water for making steam is used over and over in the boiler without any new feed water except what is necessary to supply the loss due to leakage of the boiler and the various connections from the boiler through the engine and condenser back to the boiler. And, as but little new feed water is needed, the boiler may be kept very free from scale and sediment. This, of course, is a great point in their favor for use at sea, where it is desirable to get as little salt water into the boilers as possible.

The main objection to the surface condenser is the fact that when the

tubes get hot they expand, and then are likely to become loose and leak. They are also apt to "creep"—that is, work out of the bearing at one end. Some dozen or more methods of fastening the tubes, so that they may expand and contract without working loose or creeping, have been tried. Some do well and others do not.

Condensing the exhaust steam from an engine diminishes the back pressure by creating a partial vacuum behind the piston.

This vacuum is generally spoken of as being of so many "inches of mercury," each inch of mercury representing a diminution of about half a pound in the back pressure, and, therefore, a corresponding increase in the mean effective pressure on the piston.

Thus a vacuum of twenty-six inches means that the back pressure has been reduced about thirteen pounds per square inch, or that the engine, instead of working againt a back pressure of fifteen pounds per square inch, is working against a back pressure of only two pounds per square inch. A vacuum of twenty-six inches cannot always be obtained, or, even if attained, cannot be always maintained. But one of twenty inches may be safely assumed for almost any condenser.

The expression for the work an engine will do per minute is

$$W = Pe \,.\, L \,.\, A \,.\, N.$$

Where Pe is the mean effective pressure in pounds per square inch of the steam on the piston: L, the length of the stroke in feet; A, the area of the piston in square inches, and N, the number of strokes made by the engine per minute.

A, L and N may be considered constant for any given engine, and their product may be represented by K.

Then $W = K \,.\, Pe$.

If P represents the initial absolute pressure of the steam in the cylinder, r, the number of times the steam is expanded, and P_1 the mean back pressure per square inch, then

$$Pe = \frac{P \,.\, (1 + \text{hyp. log. } r)}{r} - P_1$$

$$\text{and } W = \frac{K \,.\, P \,.\, (1 + \text{hyp. log. } r)}{r} - K \,.\, P_1.$$

If now a condenser is attached to the engine, and the back pressure is reduced to P_2 pounds per square inch, the work it will then be capable of doing is

$$W_1 = \frac{K \,.\, P \,.\, (1 + \text{hyp. log. } r)}{r} \; K \,.\, P_2.$$

$$K \,.\, P \,.\, \frac{(1 + \text{hyp. log. } r)}{r} - K \,.\, P_2.$$

The per cent. of additional work the engine can do with the condenser over what it did without it is

$$f = \frac{W_1 - W}{W} = \frac{P_1 - P_2}{\frac{P\,(1 + \text{hyp. log. } r)}{r} - P_1}$$

If it were desired that the engine should do the same amount of work after the condenser is attached to it that it did before, it would be necessary to reduce the initial pressure of the steam or to make the engine cut off earlier in the stroke.

Equating the expressions for W and W_1, and solving the equation thus obtained, it is found that the initial absolute pressure of the steam with which the engine will do the same amount of work with a condenser that it did without one, is,

$$P^1 = P - \frac{r(P_1 - P_2)}{1 + \text{hyp. log. } r}.$$

If now it be assumed that the pressure of the steam in the boiler is equal to its initial pressure in the cylinder, as it is very nearly, it is seen from the equation that, when the condenser is attached to the engine, the boiler pressure may be reduced

$$\frac{r(P_1 - P_2)}{1 + \text{hyp. log. } r} \text{ pounds per square inch.}$$

If it be desired that the engine continue to do the same work, and that the boiler pressure should remain the same, then, when the condenser is attached the point of cut-off must be changed from $\frac{1}{r}$ to $\frac{1}{r_1}$, or the number of times the steam is expanded from r to r_1.

The value of r_1 is obtained by equating the value of W and W_1, and solving the equation thus obtained for r_1.

The equation is :

$$\frac{1 + \text{hyp. log. } r_1}{r_1} = \frac{1 + \text{hyp. log. } r}{r} - \frac{P_1 - P_2}{P}$$

This equation can be solved by trial, and the value of r_1 obtained

If the point of cut-off is changed from $\frac{1}{r}$ to $\frac{1}{r_1}$ then in the case of a jet condenser the volume of steam saved per minute will be $N.\ V.\left(\frac{r_1 - r}{r\,r}\right)$ cubic feet, less the amount necessary to run the air pump. N is the number of strokes the engine makes per minute, and V is the volume, in cubic feet, swept through by the piston at each stroke.

If the air pump is run by a cylinder independent of the engine, it is very easy to determine the amount of steam used by it per minute. But, when the air pump is run by the engine, the problem becomes difficult. It is estimated that when the air pump is connected to, and run by, the cross-head of the engine, the resistance due to it is equivalent to an additional back pressure on the piston of from 0.50 to 0.75 pounds per square inch.

The amount of water necessary to condense the steam from an engine depends upon the temperature of the steam when it leaves the engine: upon the temperature of the condensing water, both wh n it enters and when it leaves the condenser. The temperature of the steam when it leaves the engine is the temperature of steam corresponding to the final absolute pressure of the steam in the cylinder. This final absolute pressure, P, may, for all ordinary purposes, be assumed as equal to $\frac{P}{r}$, where P is the initial absolute pressure of the steam in the cylinder, and r is the number of times the steam is expanded.

The expression for the number of pounds of condensing water necessary to condense each pound of steam exhausted from the engine is,

$$R = \frac{H + t_1 - t_3}{t_3 - t_2}$$

Where H is the latent heat of steam under a pressure P_4; t_1, the temperature of steam corresponding to the pressure P_4; t_3, the temperature of the condensing water when it leaves the condenser; and t_2, the temperature of the condensing water when it enters the condenser.

For ordinary purposes H may be assumed as equal to $1114.4 - 0.7\,t_1$. Putting this value of H in the expression for R it becomes

$$R = \frac{1114.4 + 0.3\,t_1 - t_3}{t_3 - t_2}$$

It is evident from the formula that the greater t_1 is, the greater R will be. Also, the greater t_3 is and the less t_2 is, the less will R be.

t_1 will be large or small, according as P_4 is large or small, and for a given initial absolute pressure, P_4 is large or small, according as r is small or large.

t_3 may be any temperature between t_2 and t_1. If t_3 is large, then the pressure due to the vapor in the condenser will be large, and it will be difficult to obtain any considerable diminution of the back pressure on the engine. While, if t_3 is small it will take a large quantity of water to condense the exhaust steam.

Boume recommends that the condensing water be allowed to leave the condenser at about 100 degrees Fahrenheit. On marine engines it is usually assumed as about 110 degrees Fahrenheit.

The temperature t_2 of the condensing water when it enters the condenser depends upon the source from which the water is drawn. Everything else being the same, a condenser will require less water in winter than in summer. Since, in the winter t_2 will be less than in the summer.

In designing a condenser it is necessary to assume the smallest value of t_3 that is likely to occur and the greatest value of t_2.

Before a condenser is bought and connected to an engine, the engine should have an indicator card taken from it by a competent engineer. If that is done it will be easy to determine

1st. The per cent. of increase of work the engine can do with the condenser over what was done without it.

2d. The amount the initial pressure may be reduced and the engine continue to do the work with that it did without the condenser.

3d. The point in the stroke to which the cut-off may be changed and the engine continue to do the same work with that it did without the condenser.

4th. The number of gallons of water required per minute to condense the steam from the engine.

TABLES.

For ordinary practice, when an indicator card cannot be taken from the engine, Table 1 may be used to determine the number of gallons of water necessary to condense the exhaust steam.

Table 2 may be used to determine the additional work that can be done by the engine with the condenser ; the change that may be made either

in the boiler pressure or the cut-off, and the engine continue to do the same work with that it did without the condenser.

The tables should be used only when it is impossible to have the advice and skill of a competent engineer.

TABLE 1.

Pressure per gauge in boiler.	Cut-off at ¼ stroke. Gallons of water to condense 1 lb. of steam.	Cut-off at ½ stroke. Gallons of water to condense 1 lb. of steam.	Cut-off at ¾ stroke. Gallons of water to condense 1 lb. of steam.
60	2.567	2.595	2.613
70	2.570	2.600	2.620
80	2.575	2.605	2.625
90	2.580	2.610	2.630
100	2.583	2.614	2.635

TABLE 2.

Pressure per gauge in boiler.		Cut-off at ¼ stroke.	Cut-off at ½ stroke.	Cut-off at ¾ stroke.
60	A	34	21	17
	B	0.17	0.35	0.48
	C	43	48	50
70	A	28	18	15
	B	18	0.37	0.50
	C	53	58	60
80	A	24	15	13
	B	0.19	0.38	0.53
	C	63	68	70
90	A	21	13	11
	B	0.19	0.39	0.54
	C	73	78	80
100	A	19	12	10
	B	0.20	0.40	0.56
	C	83	88	90

A is the additional per cent. of work engine can do with the condenser.

B is the point to which the cut-off may be changed and the engine continue to do the work with a condenser that it did without one.

C is the point to which the boiler pressure may be reduced and engine continue to do the work with a condenser that it did without one.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

DECEMBER 19, 1888:—A regular meeting was held at the Society's rooms, Boston & Albany railroad station, Boston, at 19:30 o'clock, President FitzGerald in the chair, fifty-three Members and eleven visitors present.

The record of the last meeting was read and approved.

Messrs. Henry F. Bryant, Levi G. Hawkes and George A. King were elected Members of the Society.

The following were proposed for membership:

Arthur G. Fogg, Norwood, Mass., recommended by L. B. Bidwell and H. C. Keith: Henry M. Howe, Boston, recommended by Albert H. Howland and H. A. Carson: Walter H. Richards, New London, Conn., recommended by R. C. P. Coggeshall and Dexter Brackett, and Walter S. Whiting, Cambridge, Mass., recommended by F. L. Libbey and F. P. Spalding.

On motion of Mr. Howe, the Secretary was instructed to convey to the President of the West End Street Railway and to the Sprague Electric Motor Company, the thanks of the Society for courtesies received this afternoon on the occasion of the trip over the new electric railway line in Brookline and Brighton.

On motion of Mr. Tilden, it was voted that the President appoint a committee to confer with other engineering or scientific societies in Boston to ascertain the practicability of establishing a common headquarters.

The President has named as that committee Messrs. James A. Tilden, Thomas Doane and Frederick Brooks.

Vice-President Stearns then assumed the chair, and called on Mr. John R. Freeman, who read a very interesting paper on "Stadia Work."

Mr. Henry B. Wood described the work accomplished with the stadia on the Mississippi River Survey.

Mr. Wm. E. McClintock compared the work of the plane table with that of the stadia, strongly favoring the former, and the two methods were further discussed by Messrs. Adams, Allen, Burton, Cutter, Hale, Hodgdon and Smith.

[*Adjourned.*] S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

DECEMBER 5, 1888:—297th Meeting.—The Annual Meeting was held at Washington University. President Holman called the meeting to order at 8.20 P. M., there being thirty-two Members present. The minutes of the 296th meeting were read and approved as corrected. The Executive Committee reported the meetings of November 28 and December 5. The resignations of Henry B. Wood and Jas. E. Mills in good standing were announced. The Committee having approved the applications for membership of Wm. F. Schaefer, Louis Simonds and H. D. Wood, they were balloted for and elected. At this point the regular order was suspended, and a Committee consisting of S. B. Russell, Robert Moore and R. E. McMath was elected to submit late in the evening nominations for officers for the coming year.

The following applications for membership were announced: Fred. W. Abbot, Draughtsman St. Louis Water-Works Extension; Endorsers, S. B. Russell and M. L. Holman. Leroy Bartlett, Master Mechanic Missouri Pacific Railway; Endorsers, M. L. Holman and W. H. Bryan. Oscar W. Ferguson, City Sewer Engineer; Endorsers, R. E. McMath and Wm. Wise. Abram N. Milner, Superintendent Construction City Sewer Department; Endorsers, R. E. McMath and Wm. Wise. Lemon Parker, with Parker-Russell Mining and Manufacturing Company; Endorsers, Russell Parker and S. B. Russell. H. R. Stanford, Instructor at Manual Training School; Endorsers, C. E. Jones and W. H. Bryan.

The annual reports were then read from the Executive Committee, Secretary, Librarian and Treasurer, as follows:

REPORT OF EXECUTIVE COMMITTEE.

St. Louis, Mo., Dec. 5, 1888.

To the Engineers' Club of St. Louis:

Gentlemen: Your Executive Committee takes pleasure in submitting the following report: The past year has been one of increased prosperity. The committee has held 18 meetings, approved 17 papers for publication in the Journal, received 27 applications for membership, recommended 25 of the applicants for election, received four resignations, dropped four names and announced one death. Forty bills have been approved for payment, as follows:

For the Journal	$493.25	Index to library	$35.06
Printing	112.20	Supper menu	10.00
Postage	34.85	" deficit	15.00
Association of Engineering Societies	21.00	Total	$732.30
Janitor	12.00		

Your Committee has recommended, and the Club approved, an allowance of $100 per year for the Secretary's services.

TREASURER'S REPORT.

Dec. 5, 1888.

The Engineers' Club of St. Louis:

Gentlemen: I have the honor to submit the following report:

To balance as per report Dec. 7, 1887		$418.24	
" " 1887, receipts on hand Dec. 7, 1887		185.00	
" receipts issued for 1888 dues		652.00	
" " " " new Members		259.00	
Received from Banquet Committee		4.85	
Rebate from *R. R. Gazette*		8.50	
Assessment account 20th Anniversary Supper		15.00	
Received from J. F. Porter		2.00	
			$1,544.59
By vouchers paid	$719.30		
" rebate on dues	35.50		
" dues receipts cancelled by Ex. Com	54.00		
" " " on hand	136.00		
" balance uncollected on account 20th Anniversary Supper Asst	6.00		
			950.80
			$593.79
In Provident Bank	52.54		
In St. Louis National Bank	510.80		
Cash	30.45		
			$593.79

Chas. W. Melcher, Treasurer.

SECRETARY'S REPORT.

Your Secretary begs leave to submit the following report for the year past:

There have been 16 meetings, 14 regular and 2 social. The regular meetings have all been held at Washington University. President Holman occupied the chair at 14 meetings, Vice-President Meier at one, and Prof. Nipher at one. The total number of recorded meetings is now 296. The average attendance at meetings has been 28, an increase of 7 over last year and 9 over the year before. Total attendance of visitors for the year was 50. Papers were read at all the regular meetings. Those presenting papers were P. M. Bruner, I. A. Smith, C. H. Led-

lie, F. E. Nipher, N. W. Eayrs, C. C. Brown, C. Gaylor, B. F. Crow, O. L. Petitidier, H. B. Gale, R. Moore, S. F. Burnet, W. Beahan, S. B. Russell, E. D. Meier, C. F. White, L. Stockett and R. E. McMath. In addition there was an address by retiring President Potter. Twenty-six new Members have been elected; of these 3 have not yet qualified. There have been 4 resignations, 4 names dropped and 1 death, Mr. Shickle. Our membership is now 150—104 resident, 45 non-resident, 1 honorary. Respectfully,

WM. H. BRYAN, Secretary.

LIBRARIAN'S REPORT.

ST. LOUIS, Dec. 3, 1888.

The library of the Club has been increased during the past year by over one hundred books and pamphlets, many of them of considerable value, which had come into the possession of your Librarian in his capacity of Manager of the Index Department of the Journal. Although this matter has been set apart by the Managers of the Journal as part compensation for preparation of the Index Notes, yet it was thought best to turn it over to the Club and so increase its usefulness.

The entire library has been catalogued by Mr. C. V. Mersereau, Member of the Club, upon cards, not by titles of volumes but by subjects or topics contained in them.

This has made it available for ready reference and has materially enhanced its value. Since the catalogue was prepared, Mr. C. E. Jones has presented ten bound volumes of the *R. R. Gazette* to the library.

Amongst other contributions, aside from the regular exchanges, may be mentioned a copy of the report of the aqueduct commissioners of New York City.

In order to make our library more accessible to the Members, I would respectfully recommend that it be placed in the new Mercantile Library rooms, under their care and supervision, but in such a way as to be accessible to the Members of the Club. Some satisfactory arrangement could probably be made to that effect.

By the Constitution of this Club, the Librarian is also the representative of the Club on the Board of Managers of the JOURNAL OF THE ASSOCIATION. By the rules of that Association, where any of the associated societies shall attain a membership of 150, it may have two representatives on the Board. Since the St. Louis Club has now reached that limit, I would recommend that two names be proposed this year in place of one in the annual election. The Boston and Western (Chicago) societies already have two representatives each.

The Association is in a flourishing condition, there now being eight societies belonging, in place of four, the original number. Although the St. Louis Club has never been the largest in numbers, it has contributed by far the most matter to the JOURNAL, and is coming to be known as the best working society in the country. The programme for the current year is an indication that it has certainly not lost any of its wonted vigor. A membership in this Club is both an honor and a favorable introduction into engineering circles the country over. Its membership ought, however, to be largely increased, and could readily be with a little judicious effort. Many engineers are so modest that they hesitate to request a membership in a society, but prefer to be invited so to do. All worthy engineers should be made to feel welcome to membership among us, and I believe a little thoughtful hospitality, carried to the extent of sending such a person a blank application already signed by two Members, with a copy of the Constitution, would usually be successful. Several hundred printed copies of the Constitution and By-Laws are in the Library. Would it not be well to send each Member one of these, and also one blank application, with a circular letter asking Members to extend the hospitable invitation as above suggested to any worthy engineer of their acquaintance in this locality? There is no reason why the Club should go begging for Members, but at the same time we should extend our field of usefulness as much as is compatible with our honorable standing and our working efficiency. Respectfully submitted,

J. B. JOHNSON, Librarian.

All were accepted, that of the Treasurer being referred to the Executive Committee to be audited.

Prof. J. R. Kinealy's paper on "Condensers for Steam Engines" was then read by the Secretary. The resulting economy of fuel was explained; also the principal features of jet and surface condensers. By using condensers three results could be attained: the work that an engine would do could be increased; or, if doing the same work, either the initial pressure could be reduced; or the point of cut-off made earlier. Tables showing the results that might be expected at various pressures and cut-offs were submitted.

In the discussion Mr. Bryan called attention to the fact that the calculations were based on a vacuum of only twenty inches, which was very low. Twenty-six inches was good practice, and not uncommon, and still higher vacuums were maintained under favorable conditions. He also stated that under certain condiions a condenser might be of no benefit to an engine, particularly where it was already underloaded. The condenser would produce a still earlier cut-off, and greatly increase the cylinder condensation.

Prof. Gale showed that the particular type of engine under consideration, and its characteristic indicator card, would affect the accuracy of the results given in the paper.

Mr. Holman stated that in the practical operation of condensers many questions arose which were not touched upon in the paper. The air pumps were usually too large—not always a bad feature, however. Air pockets frequently caused trouble. The latest practice is to use two pumps, one for removing the air from the top of condenser and the other to handle water only. He called attention to the practice of putting a surface condenser in the discharge main from pumping engines. In addition to leakage some of the condensed water must be wasted, on account of grease from the cylinder lubrication. At the St. Louis Water-Works the temperature of hot well ran from 100 to 110 degrees Fah.

Mr. Chaphe stated that the water-works engines worked ordinarily with a vacuum of twenty-six inches, which in cold weather could be increased to twenty-eight.

Mr. Wheeler stated that the purer feed-water resulting from the use of surface condensers secured better evaporation from the boilers.

Colonel Meier replied that pure water was not always considered desirable, as several cases of pitting of material had been attributed to this cause. It had not been shown, however, that the result might not have been due to something else Mr. Holman stated that water thus used repeatedly might become superheated. Professor Gale thought pitting of boilers was usually traceable to the quality of oil used.

The committee on nomination of officers then submitted the following report: President, E. D. Meier; Vice-President, F. E. Nipher; Secretary and Librarian, W. H. Bryan; Treasurer, C. W. Melcher; Directors, M. L. Holman and J. A. Seddon; Member Board of Managers, J. B. Johnson.

This report was accepted and the Committee discharged.

In the general discussion Mr. Bartlett stated that he was investigating the effect of jets of steam and air as used under the Olive street cable boilers. So far he had heard of no injury, even after some years of service. Robert Moore stated that the removal of the smoke nuisance would cost steam users something, and a smoke ordinance to be of any effect must be backed by a strong public sentiment. The ordinance should declare the emission of dense black smoke from factory chimneys a nuisance.

Mr. Holman stated that where boilers were already overworked smoke was unavoidable, and it was not always possible to make the required increase of plant. At the water works, with a stack 140 feet high, it was necessary to burn twenty-four pounds of coal per square foot of grate per hour. He had found steam injurious to brick work of smoke flues.

Mr. McMath stated that a great deal of steam was discharged into sewers, and they were subject to decay. How much of this was due to steam he was not prepared to state.

[*Adjourned.*] W. H. BRYAN, Secretary

MINNEAPOLIS SOCIETY OF CIVIL ENGINEERS.

AUGUST 7, 1888:—A regular meeting was held at the Board of Education rooms, at 8 P. M., Vice-President Sublette in the chair.

In the absence of the Secretaries, the reading of the minutes of the last meeting was dispensed with.

On motion of Mr. Redfield the report of the Committee on Delinquent Dues was laid over until the next meeting.

Mr. Cappelen read a paper on "Bridge Foundation," to be continued at the next meeting.

The Society gave a vote of thanks to Mr. Cappelen.

[*Adjourned.*] GEO. E. CRARY, Secretary pro tem.

SEPTEMBER 5, 1888:—A regular meeting was held at the Board of Education rooms, at 7:30 p. m., President Pike in the chair.

In absence of the secretaries Geo. E. Crary was appointed Secretary pro tem. The minutes of the previous meeting were dispensed with.

Mr. Huntress asked instructions as to the disposal of money received, of which $75 was ordered paid and sent to the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

The Secretary was instructed to open correspondence with members of the Club as to their wishes in regard to taking the JOURNAL OF THE ASSOCIATION, and to notify said Members that no answer would be considered as a negative. The Secretary was also instructed to correspond with the Secretary of the Board of said Association as to the number required to be taken by this Society.

The Club then listened to the continuation of Mr. Cappelen's paper on "Bridge Foundation."

Voted that Mr. Fanning's paper be printed in the JOURNAL.

[*Adjourned.*] GEORGE E. CRARY,
Secretary pro tempore.

NOVEMBER 21, 1888 :—Regular meeting at the Board of Education room, 7:30 P.M., to consider questions of vital interest to the Society.

President W. A. Pike in the chair.

Minutes of the last two meetings were read and approved.

Mr. W. W. Redfield moved that Secretary notify all members that if they wish to take the ASSOCIATION JOURNAL they shall be required to pay to the Secretary the subscription price in advance, and that the JOURNAL be discontinued to all other members.

Voted that the Secretary notify all members delinquent six months or more, that if their dues are not paid on or before Jan. 1, 1889, their names will be stricken from the rolls.

Mr. Hoog offered an amendment to Article 12 of By-Laws, "That the initiation fees of this Society shall be ten dollars, and that the annual dues of each Member shall be five dollars." Laid over until next meeting. Also an amendment to Article 1 of By-Laws that the meetings of the Society shall be held on the first Wednesday of each month.

On motion Mr. Handy's resignation was accepted, and Mr. W. A. Pike was elected to fill Mr. Handy's place on the Entertainment Committee. Moved that

the Librarian correspond with Secretary John Bogart, of the American Society of Civil Engineers, asking for reports already promised.

Moved that Entertainment Committe be requested to prepare a programme for the first quarter of 1889, and that the programme be made a part of the notice of meetings.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

DECEMBER 5, 1888:—Regular meeting at Board of Education Rooms, eight P. M., Wm. De Le Barr, President *pro tem.*

Minutes of last meeting were read and approved.

Moved to consider the amendments read at last meeting.

Moved to adopt amendment to Article 12 of By-laws. Lost.

Moved to adopt amendment to Article 1st of By-laws, "That the meetings of the Society shall be held on the first Wednesday of each month." Carried.

Mr. Hunress read an amendment to Article 12 of the By-Laws: "That the initiation fee shall be ten dollars, and this shall accompany every name at the time it is sent to the Committee on Members. The annual dues shall be five dollars, payable semi-annually at the first regular meeting in January and July; and a Member elected in one half-year shall not be responsible for semi-annual dues until the beginning of the next consecutive half-year."

The Society then listened to the reading of a paper by Wm. De Le Barr, on the methods of compressing brass for shipping purposes. Voted that the paper be printed in the ASSOCIATION JOURNAL.

Mr. De Le Barr described also an ingenious device for bolting flour.

Thanks were voted to Mr. De Le Barr.

[*Adjourned.*] WALTER S. PARDEE, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

NOVEMBER 5, 1888:—The President being absent, Mr. J. L. Gillespie was chosen Chairman for the evening.

The name of Mr. S. F. Adams was proposed for membership by Mr. H. N. Elmer. The report of the Secretary was received upon the matter of the standard form of contract for buildings as proposed by the National Association of Builders, and an informal communication from the Vice-President of the said Association recommending the members to use the form of contract in any work they might let to which it was applicable.

Mr. J. D. Estabrook read a paper upon the Artesian Wells of St. Paul and vicinity, and presented some blue prints showing the location and a profile giving depth, elevation of the ground surface, height of water and some information relating to the strata passed through. Beneath the drift are found varying layers of limestone and sandstone. The wells vary from 200 to 1,600 feet in depth, and but few are flowing wells. The larger portion require the water to be pumped. This is a subject of local interest, as the Board of Park Commissioners have under consideration a plan to supply Como Park (200 acres) and Como Lake, 80 acres, by water from an artesian well to be sunk in the park, no other supply been available.

[*Adjourned.*] GEO. L. WILSON, Secretary.

DECEMBER 3, 1888:—The monthly meeting was held in the Rynn Hotel, L. W. Rundlett Chairman in the absence of the President, 18 Members 1 visitor present.

The application of E. E. Woodman for membership was received.

The paper of the evening was read by Mr. S. D. Mason upon the "History of a High Viaduct" built in 1883–4 by the Northern Pacific Ry. over Mount Gulch. The height of the viaduct at the centre is 216 feet. The timber was cut and sawed

near the spot. The iron and supplies brought were hauled 80 miles. In 1885, after the road was in operation, the wooden viaduct was replaced with an iron viaduct from designs by Geo. S. Morison, C. E.

Mr. Mason's paper was illustrated by photographs of the wooden and of the iron structure and prints of the working drawings of the two structures. After discussion the meeting adjourned to the hotel café for a lunch and an hour of social intercourse. GEO. L. WILSON, Sec'y.

ENGINEERS' CLUB OF KANSAS CITY.

DECEMBER 3, 1888:—A regular meeting was held in the club room, at 8 P. M., G. W. Pearsons in the chair.

There were present six Members and three visitors.

Minutes of the previous regular meeting and the meeting of the Executive Committee were read and approved.

The Secretary mentioned the following received for the library: *The Technic*, Transactions American Society of Civil Engineers, Transactions Engineers' Society of Western Pennsylvania.

Mr. Clarence A. Burton read a paper on "The Steam Engine; its Beginning, Growth, and Place in the Industries of To-day," which was discussed by Messrs. Pearsons and Wynne.

The paper on "Shrinkage of Material" was postponed on account of the lateness of the hour.

Frederick C. Gunn was proposed as Associate Member by E. I. Farnsworth and W. B. Knight.

[*Adjourned.*] KENNETH ALLEN, Secretary.

DECEMBER 5, 1888:—The Annual Meeting was held in the club-room at 8 P. M., President Wm. B. Knight in the Chair. There were present 14 Members and 2 visitors.

Reports for the past year were presented; for the Executive Committee by the President, by the Secretary and Librarian, by the Treasurer; and for the Committee on Bridge Reform by W. H. Breithaupt.

On motion of Mr. Breithaupt, it was voted to instruct the Executive Committee to expend about $40 in subscriptions to leading engineering journals.

Nominations of officers for 1889 were made as follows:

For President, O. B. Gunn, J. A. L. Waddell.

Vice-President, W. H. Breithaupt, John Donnelly.

First Director, T. F. Wynne, W. Kiersted.

Second Director, S. H. Yonge, C. A. Burton.

Secretary, Kenneth Allen, A. J. Mason.

Treasurer, F. W. Tuttle, V. M. Witmer.

Librarian, C. E. Taylor, Frank Allen.

Mr. Burton presented the Club with two photographs of a miniature Corliss engine constructed by him.

[*Adjourned.*] KENNETH ALLEN, Secy.

REPORT OF COMMITTEE ON BRIDGE REFORM.

Your Committee is glad to report that the question of bridge reform has, since its bringing forward by this Club, received a great deal of attention by the various local engineers' societies throughout the country.

To the invitation to co-operate, issued by this Society last May, there has been a general response. The correspondence from other societies has been referred to your

Committee. From the interest shown, and the action taken in the matter by the various societies, we feel confident in the hope that general better bridge practice will result. The Western Society of Engineers, the Engineers' Club of St. Louis, the Engineers' Club of Cincinnati, the Engineers' Club of Philadelphia, the Boston Society of Civil Engineers, and the Engineers' Club of St. Paul have appointed special committees on bridge reform. The Indiana Society of Civil Engineers and Surveyors, and the Engineers' Association of Kansas have had discussions on the question. All of these societies recognize the urgent need of a reform of some shape, and the prevalent opinion is that such reform should be effected by legislation.

The Committee of the Western Society of Engineers recommends appointment of a State engineer, his duty to be to examine and report on existing bridges, and who should have authority to condemn; that cities and counties be encouraged to employ bridge specialists, and that engineers agree upon a scale of minimum rates for value of their services.

The Committee of the Cincinnati Club thinks that the law to regulate bridge practice should be uniform for all States. It should specify: complete registration and filing of plans of all bridges within a certain time ; that the governor of the State should be empowered to require proper plans for new bridges and have appointment of State engineer, who should be responsible directly to him; that all dangerous bridges should be publicly condemned by the State ; that bridge owners should be held accountable to the State for failure of their structures; that the State bridge engineer should thoroughly check plans of and inspect all bridges, and that he should act as advisor to the governor and legislature in all matters relating to laws, regulations and public use of bridges in the State ; that owners should be heavily fined for bridge failures or for any non-compliance with bridge laws, and should be prosecuted by the State for manslaughter in case loss of life should result from a bridge failure.

The Committee of the Boston Society is of the opinion that the Society should proceed very cautiously in the matter of recommending any legislative action which would result in State inspection of highway bridges, as it does not yet appear certain that this method in itself would secure the building of proper structures. That establishment of rates for the professional services of engineers is not to be recommended. That the Society take appropriate action on the subject and further consider, through a committee, what legislation or other action would be advisable, and to what extent it would be practicable to co-operate with other societies.

The St. Paul, St. Louis and Philadelphia societies have not yet formally reported any action to us, further than the appointment of special committees.

In preparing a draft for a suitable State bridge law your Committee profited by the suggestions from the other societies. This draft was read at the regular November meeting of the Club. Since then we have been favored with the opinion of Mr. Henry Smith, of this city, for a number of years a State legislator. At an informal conference in Chicago last week, at which were present a number of the Chicago committee, one of the St. Paul committee and two of your committee, our draft was also fully gone over and discussed. On the whole we find a number of modifications in our original draft desirable. These being such, your committee would recommend that the said draft of State bridge law be printed, circulated to the other engineering societies with request for their comments thereon, and the draft finally modified, if it is desirable, as early in January as possible, as it is thought best to have it in shape by that time for presentation to the State Legislature.

Committee. { O. CHANUTE.
J. A. L. WADDELL.
W. H. BREITHAUPT.

ANNUAL REPORT OF THE SECRETARY AND LIBRARIAN FOR THE YEAR 1888.

I have the honor to present to you the following report for the year ending December 5, 1888.

At the annual meeting held January 9, the following officers were elected:

President—Wm. B. Knight.

Vice-President—Octave Chanute.

Directors—T. F. Wynne and W. H. Breithaupt.

Secretary, Treasurer and Librarian—Kenneth Allen.

February 6th, on resignation of the latter as Treasurer, J. A. L. Waddell was elected to that office, and it was voted to amend the Constitution by including the Treasurer in the Executive Committee.

During the year there have been held:

One annual meeting. Ten regular meetings.

Three adjourned meetings. Twelve Executive Committee meetings.

The attendance at the regular and adjourned meetings has been:

		Increase over 1887.
Members, total	169	47, or 38½ per cent.
" average	13	2 " 18 "
Visitors, total	84	53
" average	6.5	3.5

Papers presented have been as follows:

January 9, Address by the President, Wm. B. Knight.

February 6, The Inspection of Iron Bridges and Viaducts, by B. L. Marsteller.

March 5, Engineers' Field Books, Edw. Butts.

April 2, Reform in Highway Bridge Building, J. A. L. Waddell.

April 16, Discussion of Highway Bridge Building.

May 7, A Talk on Asphalt Pavements, A. J. Mason.

June 4, Crossing of the C., S. F. & C. over the M. P. and C. & A. Railroads, near Rock Creek, W. H. Breithaupt.

June 18, Street Pavements of Kansas City, John Donnelly.

September 3, Flood Waves of the Missouri River, J. F. Wallace.

October 1, The Complete Sewerage of Kansas City, A. J. Mason.

November 5, Electric Railways, T. F. Wynne.

November 19, The Present Status of the Electric Railway Problem, Wellington Adams, M. D.

December 3, The Steam Engine; Its Beginning, Growth, and Place in the Industries of To-day, C. A. Burton.

In addition to the meetings, the Club held its annual supper January 9, at the Brunswick Hotel, and July 28 an excursion over the K. C. W. & N. W. Ry. to Leavenworth, attended by 27 Members and 42 guests.

Memorials were sent to our representatives at Washington endorsing the Breckenridge Bill (by the Committee on National Public Works), and urging the establishment of self registering rain gauges (by W. Kiersted). The passage of the above bill was urged by the Club through Mr. Wm. B. Knight, who was sent by the Club as delegate to Washington April 10.

The Committee on Highway Bridge Reform has in preparation a memorial to present to the State Legislature. An active interest has been generally awakened in this movement, as is shown by favorable action having been taken by the Philadelphia, Boston, Cincinnati, St. Louis, Chicago, Indiana and Kansas societies.

The question of inviting the American Society of Civil Engineers to visit Kansas City at their next annual convention has been informally discussed, but as yet no action has been taken.

There also lies before the Club the election of a Representative on the Board of Managers Association Eng. Soc., the present Secretary having filled that position provisionally since Mr. Chanute's absence in October.

October 1st the Club took possession of their new quarters in the Y. M. C. A. Building. The club-room is modest in size, but meets the requirements of a sitting and reading room for the present, and at a moderate expense. Photographs donated during the year by Messrs. A. J. Tullock, W. D. Jenkins and W. H. Breithaupt decorate the walls.

Membership.

	Hon.	Members.	Assoc.	Assoc. Mem.
December 19, 1887	0	45	0	1
Additions	0	22	0	7
	0	67	0	8
Resignation	0	2	0	1
	0	65	0	7
Dropped for non-payment of dues	0	3	0	1
	0	62	0	6

It is noticeable that within the year the number of non-resident members has increased from 6 to 22.

Several valuable additions have been made to the library, but it has been thought best not to incur expense in purchasing books or periodicals, therefore it remains but a beginning, a nucleus ready for development. It is thought the time has come when a moderate sum might be advantageously applied to the subscription of several engineering magazines, and to the collection of books of reference. The selection of these might properly be left to a Library Committee, who could receive suggestions from Members as to what works would be most acceptable, and then use their discretion in the disposal of such funds as might be appropriated by the Executive Committee for such purposes. When it is once realized by the Members that they can spend to their profit an occasional half hour in the reading-room, I believe a decided point will be gained in usefulness and prosperity of our Club.

During the year the following have been received for the library:

Transactions American Soc. C. E., 1888.

Transactions American Soc. Mech. Engrs., 1887 and 1888.

Transactions Engineers' Club of Philadelphia, 1888.

Transactions Engineers' Soc. of Western Pa., 1888.

Transactions Indiana Soc. of C. Es. and Surveyors, 1888.

Transactions Illinois Soc. of Engrs. and Surveyors, 1888.

Transactions Engineering Assc'n Lehigh Univ., 1888.

Transactions Engineering Soc. School of Practical Science, Toronto, 1888

Transactions Engineering Society, University of Michigan, 1888.

Transactions National Association of Builders, 1888.

Journal of New England Water-Works Association, 1888.

The Electro Mechanic, 1888.

The Railway Review, sundry copies.

Theory and Practice of Surveying, by Prof. J. B. Johnson.

Engineers' Field Book, by Edw. Butts.

Official Railway List, 1888.

The Lakes and Gulf Waterway.

Respectfully submitted,

KENNETH ALLEN, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

DECEMBER 15, 1888 :—The regular monthly meeting was held at the office of Mr. E. H. Beckler, Chief Engineer M. C. Ry., at 8 P.M., Mr. Geo. O. Foss in the chair. There were present Messrs. Foss, Smith, Cumming, Ellison, Wade, Wheeler, Keerl and one visitor.

The minutes of previous meeting were read and approved.

The application of Mr. J. R. Dewitt to become a Member of this Society was read and ordered filed, and the Secretary instructed to issue the usual letter ballots upon same.

Mr. G. E. Ingersoll was, upon motion, carried, unanimously re-elected a Charter Member of this Society.

The consideration of the report of the Committee upon an overhead crossing for the motor line at Sixth avenue and Main street, Helena, was taken up as unfinished business. The report was discussed at length, in the course of which several motions, amendments and substitutes were made and withdrawn, it being the sense of the meeting that data of a more detailed character should be furnished before the Society could properly frame a resolution upon the subject.

Mr. A. E. Cumming, City Engineer of Helena, offered to furnish the Society at the next meeting with plans, profiles, etc., embodying all data affecting the proposed overhead crossing, if the further consideration of the matter was delayed until that time. The offer of Mr. Cumming was accepted, and the subject placed in the order of unfinished business for the next meeting.

Discussion followed upon a programme for the annual meeting. It was moved and carried that the Chair appoint a committee of three to act as the Committee of Arrangements for the annual meeting to be held January 19 next, and that they make a preliminary report of programme at an adjourned meeting. The Chair announced as such committee Messrs. J. S. Keerl, A. E. Cumming and John Herron.

Meeting adjourned to December 22 next to consider report of said Committee.

J. S. KEERL, Secretary.

DECEMBER 22, 1888:—An adjourned meeting was held at 8 P. M., at the office of Mr. Beckler, Chief Engineer M. C. Ry., Mr. W. W. de Lacy in the chair.

Minutes of previous meeting were read and approved.

The application of Mr. C. S. Haire to become a Member of the Society was read and ordered filed, and letter ballots ordered issued upon same.

The Committee of Arrangements for the Annual Meeting made the following verbal report:

Regular meeting to be held January 19 next at 7:30 P. M. at the office of Mr. E. H. Beckler, Chief Engineer M. C. Ry., for the transaction of general business, election of Officers and Members under ballot. It being suggested that this meeting dispose of all routine business, that the more interesting features of the Annual Meeting to occur at Butte may be thus relieved and given sufficient time for their accomplishment.

The regular meeting to be adjourned to January 21, at 8:15 A. M., to meet at Montana Central Railway depot to take train for Butte.

From time of arriving at Butte, examinations of mines and other matters of engineering interest to be made until evening, when Officers will be installed, professional papers read and discussed, etc.

Later in the evening the Annual Banquet of the Society to take place.

The Committee request that E. H. Wilson and A. B. Knight of Butte be added to their number.

On motion, carried, the report was approved and Messrs. Wilson and Knight added to the committee.

The Committee of Arrangements discussed at length with Members certain details incident to the Annual Meeting.

Meeting adjourned to January 19 next, at 7:30 P. M., to meet at same place.

J. S. KEERL, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES
ORGANIZED 1881.

Vol. VIII. February, 1889. No. 2.

THE WEST POINT TUNNEL.

BY WM. H. SEARLES, MEMBER OF THE CIVIL ENGINEERS' CLUB OF CLEVELAND.
[Read August 14, 1888.]

The United States Military Post of West Point is located upon a nearly level plateau on the west bank of the Hudson River and at an elevation of about 160 feet above tide. The plateau occupies a nearly rectangular promontory jutting diagonally into the river, and commanding the stream both above and below the point. The shore is generally rocky and precipitous.

In the early surveys for a railroad on the west side of the river, the line was projected to follow the shore around the point, involving a large amount of curvature with short radii, but this line was abandoned before construction began in favor of the more direct tunnel route.

The road as constructed comes from the south, clinging to the rocky shore upon a ledge blasted out to receive it, and then, after following an embankment in the river for a quarter of a mile, enters the tunnel upon a four degree curve, which extends about 600 feet beyond the portal. The remainder of the tunnel is on a tangent, the total length between portals being 2,664 feet. The south approach is 148 feet long, and the north approach 184 feet. The road emerges at the north end, directly upon the great bend of the river, formerly known as West Point bay, but which is now solid ground west of the railroad embankment. Relatively to the military post the tunnel passes under the riding-hall, the library, the chapel, the parade-ground, the circular depression known as execution hollow, the ordnance yard and the gas works.

The tunnel was located by the writer in March, 1872, under the disadvantages of high winds, low temperature (six to twelve degrees), and drifting snow. The precipitous character of the approaches, the presence of the river at each end of the tunnel, and the obstruction to sight and measurement [illegible] by several large buildings on the line, necessitated great care and patience on the part of the corps to secure trustworthy results. The instruments were an ordinary railroad transit and level, and New York rod, steel tapes adjustable for temperature, and flat-faced flags, with a spirit level attached to each. The latter were used for plumbing in connection with the measurements, as a plumb line would have been useless in such windy weather. Every point of measurement

was defined either by a tack in a wooden hub, or by a mark on an iron plug driven into a drilled hole in the rock. All horizontal measurements were noted to one hundredth of a foot, and the angles were read by estimation to ten seconds. The tunnel tangent was referenced by a natural object sharply defined on the mountain across the river to the southward, and by an iron bolt on the shore across the day to the northward. During the following summer the field work of the tunnel was carefully verified and was found to be accurate in every respect. Even on the curve, one end of which was 160 feet higher than the other, the deflections struck the same centres, and the chaining came out on the final point to the identical one-hundredth of a foot. Nor did this remarkable result appear to be due to any compensation of errors of appreciable magnitude. There was a slight discrepancy in the test levels, such as might be expected.

The contract for the tunnel and approaches was awarded to Sidney Dillon at ten dollars for rock in tunnel and one dollar and seventy-five cents for rock in approaches. The first blast was fired at the south approach on June 10, 1872, and work began at the north end ten days later. Several Burleigh steam drills were used, working ten hours per day. On the 18th of the following September Mr. Dillon gave up the contract by arrangement with the company, and a new contract was immediately made with F. Sweet & Co. to continue the work with the same men and tools. The excavation proceeded without interruption.

The south heading was started on November 1, and the north heading on December 6, 1872. Shortly after this the steam drills were discarded and hand drills substituted, working only one shift of ten hours per day. There was, of course, no engineering reason for this, the object being to secure continuous operation at the least expense pending the sale of the bonds in Europe. No other portion of the road was under contract at this time. Thus the work dragged along all winter, as indicated on the progress profile, until by the 1st of May, 1873, the south heading had 86 feet to show for five months' work, and the north heading only 53 feet for four months. At this time work was abandoned by the company and the engineers discharged, but the contractor continued the tunnel excavation at his own expense and without engineering direction until the next September, when the panic of the memorable "Black Friday" put a stop to all operations. The progress from May 1 to September was 110 feet at the south end and 126 feet at the north end; but the bench was taken out also, finishing the tunnel full size to within about 30 feet of the heading.

This work was not measured up until August 1, 1880, after an interval of nearly seven years. At this time the same firm resumed operations, having made a favorable contract with the new railroad company after receiving compensation for the old work done. The instrumental examination of the tunnel showed that it conformed tolerably well to line and grade. The work, so far, was all in solid granite, quite dry at the south end and with but a slight dripping at the north end. The old monuments of the line at each end were readily found, though covered with débris, and the tunnel lines were carried forward from them without any further verification.

The theoretical section of tunnel as now adopted was 27 feet wide between vertical sides, by 20 feet 6 inches high at the crown above subgrade, and the floor was depressed 6 inches below subgrade along the centre line for drainage. The theoretical roof was a semi-ellipse, with a rise of 9 feet. There was a rising grade of 0.10 per 100 from the north end and of 0.20 per 100 from the south end.

The work was now prosecuted with great vigor. An engine and boiler house was erected on made ground (for want of any better place) near the river at the north end. An air compressor of 150 horse-power was put in and set in operation by August 1, 1880. The compressed air was conducted from the receiver by 4-inch pipes to either end of the tunnel. Ingersoll drills were employed, and the headings were illuminated by electric lights. Two shifts of ten hours each per day were adopted. The headings were continued at the roof, and were made as wide as the tunnel limited by the arch form of the roof. The enlargement to grade followed about 30 feet behind the heading. A track was laid at each end, and the broken rock was hauled away in dump cars by mules to the embankments in the river.

A peculiar hoist, worked by compressed air, was invented by Mr. Sweet, and placed in the south working to load the large fragments of rock into cars. It stood on the centre line, leaving space for a car-track on each side. It had sufficient power to lift the largest pieces, but drew so heavily on the supply of compressed air as to interfere with the drilling, and on the whole it did not prove economical, requiring as much air to lift a small fragment as a large one. After a few weeks' trial it was withdrawn, and an ordinary derrick substituted.

During the winter the compressed air passing through the long pipe to the south end became so cold as to clog up the exhaust of the drills with ice and prevent their working. A heating chamber of iron, supplied with a few coils of pipe, and heated by fire at the bottom like an upright boiler, was placed in the tunnel and the air made to pass through it on its way to the drills. This not only put an end to the ice on the on the drills, but also perceptibly increased the mechanical effect in their working at a trifling cost for fuel.

In the early operations of 1872–3 only nitro-glycerine was used, but after resumption of work in 1880, the safer form of giant powder was employed for blasting purposes.

During the first two months the progress was slow, owing to various unavoidable hindrances within and without the tunnel, but after October 1 the progress in the south working averaged 119.3 feet per month for ten consecutive months, the maximum monthly advance being 142 feet in February, 1881. Could the same rate have been maintained at the north heading the tunnel would have been completed by August, but such was not the case. The material from the south end onward was solid granite with a few seams, and no water of any consequence. The north heading showed the rock more seamy and sometimes shattered and wet. It was necessary to take down a large extra amount of rock to make the roof safe. However, nearly the same progress was made here as at the south heading until October 13. 1880, when a wet spot in the roof at Station 73, which had been discharging

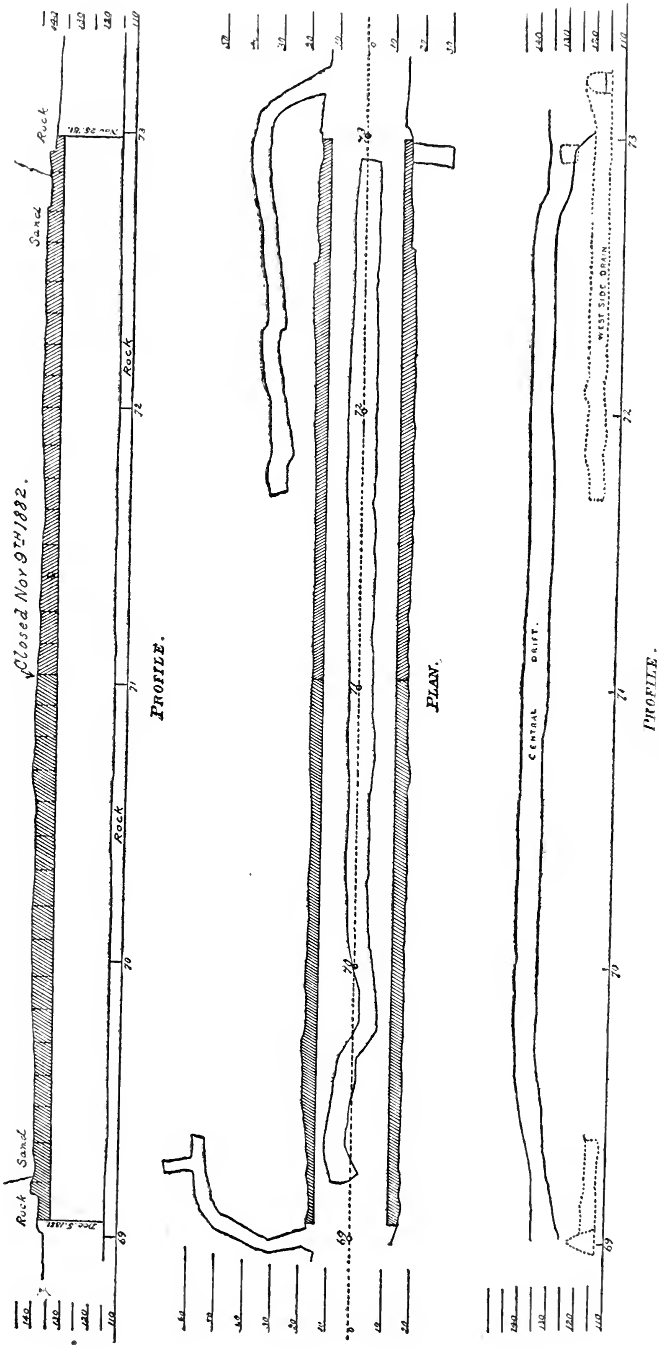
water and mud for several days, but which had been carefully propped with heavy timbers and was supposed to be safe, suddenly gave way, leaving a ragged hole some 8 feet in diameter, through which poured down a torrent of saturated sand and gravel, which only ceased when the tunnel was filled to the roof at this spot, the slope of gravel reaching nearly to the entrance, 280 feet away, The heading was about 25 feet in advance of the break in the roof, but fortunately no men were there, all having just gone out to dinner, when the accident occurred.

The flow of material into the tunnel caused the grassy surface, 85 feet above the roof, to cave in. A funnel-shaped hole, 50 feet in diameter and 40 feet deep, developed just north of the ordnance yard, undermining a portion of the cut-stone wall and one corner of the laboratory. As the hole was forming a workman, stepping to the brink, was drawn in and sucked through the vortex into the tunnel, where his remains were found unmutilated some days later. Even his dinner pail was still in his hand.

The contractor began at once to excavate the loose material in the tunnel, but no sooner was the vent freed than fresh torrents of wet sand rushed down, filling the tunnel more completely than before, while the funnel on top enlarged to 70 feet in diameter and 60 feet in depth. The surface material was hard pan to a depth of 20 feet and prevented the sides from caving in any further. Below this there was evidently nothing but sand and water to within a few feet of the tunnel roof. To choke the hole in the roof large quantities of heavy timber and of tree tops loaded with large stones were thrown in from above until the movement of sand was arrested. The sides were then stayed with plank and horizontal braces. At the same time a small timbered drift was worked through the soft material in the tunnel, and after one month's labor the original rock heading was again reached. The hole continued to discharge a stream of water, and the roof was so weak as to require arching for a length of 70 feet. A segmental brick arch of six rings was used, resting on skew-backs cut in the native rock. The weakest part of the roof was supported temporarily by heavy wooden "bars" and struts. The bars were left in when the arch was built, and these caused the arch to leak at the crown by detaining the water there, although abundant "skuppers" were left for its discharge at the skew-backs.

The contractor afterward made an attempt to intercept this water by drifting into the west side of the tunnel near grade, and after going 25 feet, turning twice to the left and returning toward the tunnel, the drift being nearly as steep as a staircase, so as to pass over the arch. But having reached a point over the west skew-back, and although still in solid rock, he feared to carry on the drift toward the crown, and so failed to stop the leak, although a large amount of water came down the "staircase." The leak in the arch continues to this day. The drift was extended south over the skew-back line a short distance, but without effect.

Nearly four months time was lost by the accident described, so that by the first of February, 1881, the total advance of the north heading had been only 26 feet since October 1st, as against 480 feet in the south heading during the same time. But now the roof became firm and excellent



MONTHLY PROGRESS SHEET OF TUNNEL MASONRY.

progress was made for several months, and it was confidently estimated that the headings would meet in the following September.

About June 10, 1881, a drill working horizontally in the north heading broke through into sand, the rock terminating with a steep face nearly at right angles to the tunnel. The sand was not free from water. This event made an entire change of operation necessary. The drills and compressed air were withdrawn, and a plant prepared for tunneling in sand. The south heading came up to the sand about the first of August. There were then 365 feet remaining between the headings. The first thing in order was to drive timbered headings to a meeting point.

This proved to be very slow work at first. The transition from rock to sand was accompanied with many difficulties and dangers. The pressure in the sand was enormous, and many of the "sets" showed distress and had to be doubled. Quicksand was encountered at the south heading, and proved so troublesome that the drift had to be carried to one side of the centre line to avoid the "pocket."

On the 19th of October, 1881, the headings met at station 71, or 982 feet from the north end and 1,682 feet from the south end of the tunnel. This drift was constructed several feet above the theoretical crown, so as to leave room for timbering the tunnel above the arch. Owing to the difficulty of transit work in the crooked drift the lines were three inches out when they met in the heading, but all discrepancies disappeared when the enlargement gave opportunity for a direct sight along the tangent. The levels met with great accuracy.

When the sand was encountered it was supposed that side walls supported by an invert would be required. In order to drain the invert a ditch three feet deep was blasted out of the floor of the tunnel, beginning at the north approach and reaching nearly to the sand section. Then it turned to the west and entered a drift that was made on the west side of the tunnel and about 20 feet distant from the side of the tunnel for drainage. This drift was carried about 150 feet at 3 feet below grade, and was in solid rock all the way, much to the surprise of every one. It gathered a great deal of water, and drained the sand in the tunnel so as to greatly facilitate the work of enlargement. When the sand was reached at the south end a similar side drain was begun in the west wall of the tunnel, but depending on hand drills only it progressed very slowly, and was finally abandoned after reaching a length of 70 feet.

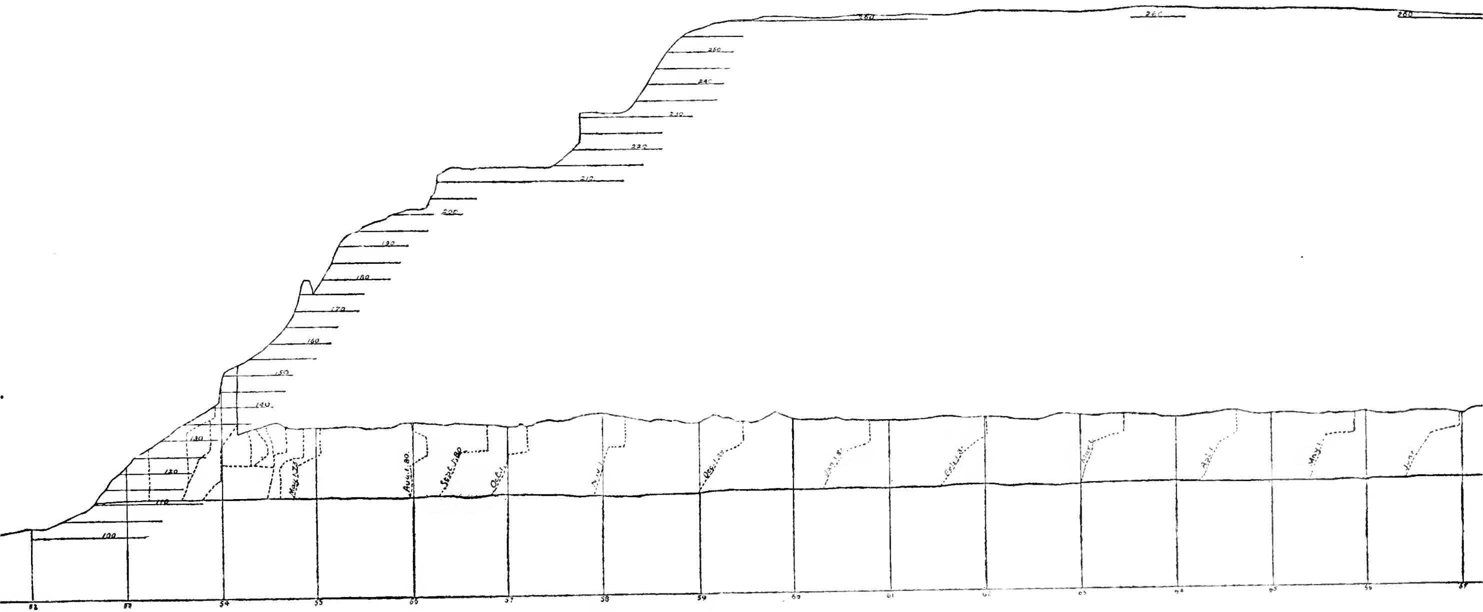
When the first sand in the tunnel was struck borings were ordered from the surface to determine the question whether any more sand was to be encountered. The borings were made by driving down gas-pipe, washed out inside by Green's driven well process. These pipes penetrated to different depths before striking rock, as indicated on the profile, but none of them came nearer than 40 feet of the tunnel roof. The presence of the second sand proved how deceptive any borings are which are not carried down to the grade of the tunnel.

After the headings met as above described there was a delay of about two months before the difficult work of enlargement proceeded; meantime the drainage tunnels were prosecuted and materials collected for arching. Four oaken logs, 2 feet in diameter and 20 feet long, were used for roof bars at each end of the work, and smaller logs for side

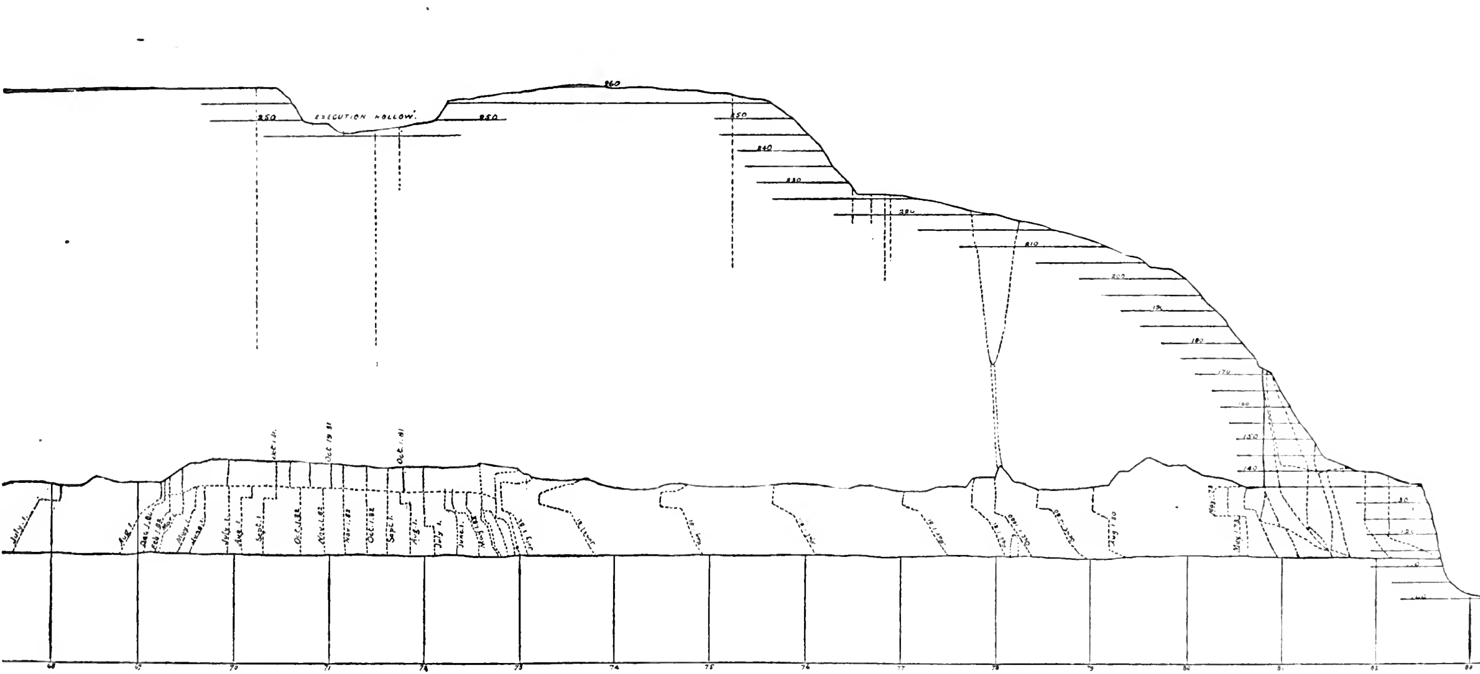
bars. A stout brattice retained the face of sand in place in the usual manner. As soon as one length of roofing formed by the bars was in place, a length or section of about 12 feet of brick arch was built under it, and after the spaces between bars had been built up from the arch to support the lagging boards, the roof bars were drawn forward, one by one, by means of a strong chain and screw, to form the next section of roofing, as in the most approved English practice. The spaces left by the roof-bars were then filled in solid with brick and slate chips. This work was carried on to completion without any serious break or mishap under the immediate superintendence of Mr. William White, since deceased, who also superintended the Musconetcong tunnel in 1872–3.

Contrary to all expectations, the sand through which the heading was driven did not extend down to grade. A rock floor above grade was found, obviating the necessity for an inverted arch. The side walls of brick were founded on solid rock throughout, and in some places the skew-back could be formed in the rock. The arch had a five centred intrados, conforming nearly to the normal semi-ellipse of 9 × 27 feet. It had a thickness of 9 rings at the springing lines, diminishing to 6 rings at the crown; it was built of hard-burned Haverstraw brick laid in mortar of Norton's cement. The ribs for the centering were built up of two thicknesses of two-inch oak plank in lengths or segments of four feet, breaking joints, with quarter-inch iron plates covering the joints, and four one-inch bolts passing through each plate. The segments were carefully jointed to resist thrust. The chord of the rib consisted of two planks two inches thick, secured by bolts at the ends. The ribs had no radial supports, and where the skew-backs would resist the thrust, the chord pieces were omitted, giving an unobstructed tunnel below the rib. The ribs were spaced four feet apart, except at the end of a section, where the spacing was two feet, to support the ends of the bars during the construction of the following section. But in the heaviest material a post was set under each drawing-bar, near the arch, as a precaution against any possible deformation. Enough centering was provided to serve two sections of the arch, and after the second was completed the centering was taken from the first section and used under the third, and so on. The brickwork was started at the north end of the arch on November 25, 1881, and the first section of 12 feet was finished on December 2. The masons then built a section at the south end, while the miners prepared another section at the north end, and so the two gangs worked alternately at either end. It was not till the first week in November, 1882, that the closing section of the arch was finished. The progress during the year is recorded on the profile and also in the table appended.

Some trimming in rock work remained to be done, and the track to be laid, and the West Point tunnel was finally completed in December, 1882, just ten years after its first inception, and two and a half years after the resumption of work in 1880. Notwithstanding the difficulties encountered the work might have been done with more dispatch, especially during the last year, had there been any necessity for it; but the road-bed was not entirely finished elsewhere, and when the tunnel was open the construction trains used it for some time to carry material southward to



WEST POINT TUNNEL PROGRESS.



WEST POINT TUNNEL PROGRESS.

unfinished embankments. It was not until the following June (1883 that regular traffic began to move through the tunnel.

The funnel-shaped hole at the surface over the first break was meanwhile refilled with earth, which had to be hauled in wagons more than a mile from the nearest available borrowing place. After the material had sufficiently settled to sustain a foundation, the stone wall and government building were restored to their original condition, and all traces of the catastrophe removed.

TUNNEL PROGRESS IN EARTH WORK.

(After completion of overhead drift.)

NORTH END.

Sec.	Length feet.	Time in days of 24 hours. Excav. d.	h.	Masonry. d.	h.	Total. d.	h.	Rate in hours per lin. foot. Excav.	Masonry.	Total.	Date of completion.
I.	12.1	....		7	..	....		....	13.9	....	Dec. 2, 1881
II.	14.8	49	18	8	12	58	6	80.7	13.8	94.5	Jan. 29, 1882
III.	11.2	32	7	8	11	40	18	69.2	18.1	87.3	March 10, "
IV.	12.6	32	9	8	1	40	10	63.7	15.3	79.0	April 20, "
V.	11.8	20	2	6	17	26	19	48.5	13.6	62.1	May 7, "
VI.	11.7	15	13	4	5	19	18	31.9	9.6	41.5	June 5, "
VII.	12.4	11	13	3	22	15	11	22.3	7.5	29.8	June 21, "
VIII.	12.1	15	9	4	8	19	17	30.5	8.6	39.1	July 11, "
IX.	12.5	11	14	3	13	15	3	22.2	6.8	29.0	July 26, "
X.	12.5	13	2	3	7	16	9	25.1	6.3	31.4	Aug. 11, "
XI.	12.2	11	18	2	8	14	2	23.1	4.6	27.7	Aug. 26, "
XII.	12.2	11	14	4	0	15	14	22.8	7.9	30.7	Sept. 11, "
XIII.	12.2	11	6	3	23	15	5	22.1	7.8	29.9	Sept. 26, "
XIV.	12.3	10	14	3	17	14	7	20.7	7.2	27.9	Oct. 10, "
XV.	11.5	9	13	4	2	13	15	19.9	8.1	28.0	Oct. 24, "
XVI.	11.0	9	18	3	7	13	1	21.4	7.2	28.6	Nov. 6, "
	195.1	266	2	79	9	338	11	34.9	9.8	44.4	
XVI.	10.8	9	11	3	4	12	15	21.0	7.4	28.4	Nov. 9, 1882
XV.	12.0	13	8	3	2	16	10	26.7	6.2	32.9	Oct. 30 "
XIV.	12.0	10	7	2	18	13	1	20.6	5.5	26.1	Oct. 14, "
XIII.	12.4	11	12	3	4	14	16	22.3	6.0	28.3	Oct. 1, "
XII.	12.0	9	5	3	3	12	8	18.4	6.3	24.7	Sept. 16, "
XI.	12.3	9	13	3	19	13	8	18.6	7.4	26.0	Sept. 4, "
X.	12.4	9	16	4	00	13	16	18.7	7.7	26.4	Aug 21, "
IX.	12.5	13	7	3	20	17	3	25.5	7.4	32.9	Aug. 8, "
VIII.	12.3	13	7	2	17	16	0	25.9	5.3	31.2	July 22, "
VII.	11.9	13	22	4	11	18	9	28.1	9.0	37.1	July 6, "
VI.	12.6	17	3	3	11	20	14	32.6	6.6	39.2	June 17, "
V.	12.8	20	21	4	7	25	4	39.1	8.0	47.1	May 28, "
IV.	11.6	33	14	6	11	40	1	69.5	13.4	82.9	May 2, "
III.	12.1	25	5	17	4	42	9	50.0	34.0	84.0	March 23, "
II.	14.8	48	14	6	17	55	7	78.8	10.9	89.7	Feb. 9, "
I.	11.8	....		11	0	....		....	22.6	....	Dec. 16, 1881
	196.3	258	21	83	4	331	1	33.7	10.2	43.1	

SOUTH END.

Both ends combined.	Ea. excav.	Masonry.	Mas. in earth.
Total length in feet........................	367.5	391.4	367.5
Total days of 24 hours....................	203.5	162.5	342.0
Average rate per day in feet............	1.8	2.4	1.1

DISCUSSION.

Mr. B. F. Morse: Why did Mr. Dillon give up his contract?

Mr. W. H. Searles: One reason was that during the months of work in these approaches he was losing money every month; besides he doubted

TABLE SHOWING PROGRESS IN ROCK-HEADING FOLLOWED CLOSELY BY FULL SECTION.

Date.	South End.			North End.			Remaining Distance, Ft.
	Station.	Rate. Ft.	Total. Ft.	Station.	Rate. Ft.	Total. Ft.	
Nov. 1, 1872.....	54.18	....	....	80.82	....	....	2,664
May 1, 1873.....	55.04	86	86	80.29	53	53	2,525
Sept. 1, 1873....	56.16	112	198	79.02	127	180	2,286
Aug. 1, 1880....	56.16		198	79.02	....	180	2,286
Sept. 10, 1880 ...	56.78	62	260	78.42	60	240	2,164
Oct 2, 1880	57.22	44	304	78.00	42	282	2,078
Nov. 1, 1880.....	58.23	101	405	78.00	....	282	1,977
Dec. 1, 1880.....	59.47	124	529	78.00	....	282	1,853
Jan. 1, 1881.....	60.79	132	661	78.00	....	282	1,721
Feb. 1, 1881.....	62.02	123	784	77.74	26	308	1,572
Mar. 1, 1881.....	63.44	142	926	77.02	72	380	1,358
Apr. 1, 1881.....	64.84	140	1,066	75.65	137	517	1,081
May 1, 1881....	65.88	104	1,170	74.47	118	635	859
June 1, 1881. ..	67.00	112	1,282	73.20	127	762	620
July 1, 1881....	68.13	113	1,395	72.80	40	802	467
Aug. 1, 1881.....	69.15	102	1,497	72.80	....	802	365

the ability of the road to continue. No doubt he was correct, for you must remember that the work ceased and was not recommenced for seven years.

Mr. Aug. Mordecai: If you had entirely missed "Execution Hollow" do you suppose you would have struck that bank of earth in the tunnel?

Mr. Searles: Possibly not, though it is probable that a valley in the rock formation filled with sand extends across any location that could have been made. As shown on this plan, we were rather limited in the position the tunnel could take. We were necessarily close along shore at the south end: to have carried the south portal further forward would have increased our curvature very much, and to have gone further back would have increased the length of the tunnel; so that risk was taken in the first place. It was not supposed that at this depth we would meet with any difficulty.

Mr. Mordecai: How wide is that hollow at right angles to the location?

Mr. Searles: It is about 200 feet. The hollow is nearly circular in plan.

Mr. M. E. Rawson: Did not "Execution Hollow" have a solid rock bottom?

Mr. Searles: No; when we drove the test pipes down they went down pretty easily till we brought up on rock at various depths, as shown. I imagine that the displacement is something in the nature of a valley. The first break occurring under the ordnance yard was doubtless due to a little valley in the rock running down toward the northeast. There was an excellent spring of cold water near the shore originally. This spring dried up when the water broke out in the tunnel. Probably when "Execution Hollow" was formed originally the soft material found its way out laterally so as to allow this displacement to be made at the surface.

Mr. Whitelaw: What was the appearance of the rock at the bottom?

Mr. Searles: It was all granite. I do not think that at any place we

had to go below grade to get to foundation. This rock was sloping and broken up just as the granite rock may be seen anywhere in that vicinity I do not think that any place was found in the tunnel that could be said to be a real water course. The drainage drifts took out the water and left the sand sufficiently dry, so that there was no great difficulty in doing work in the soft material. The usual plan is to use bars of spruce in a soft material, because they are so much lighter and yield some before breaking. Oak bars are usually considered too stiff, but in the fall of the year, when this work began, it was impossible to get large bars of spruce in time, so we were compelled to use oak. They served a good purpose without any failure, and when the two sections approached each other and finally met, the bars were left in the work above the arch.

Mr. Mordecai: What were your specifications in regard to taking the material out beyond the normal section ?

Mr. Searles: It was to be paid for at the usual price for rock excavation, $1.25.

Mr. Mordecai: The claims of the contractor for material taken outside of the normal section seem to give a great deal of trouble. The contractors in the Croton Aqueduct tunnel have made very large claims.

Mr. Searles: The drill holes were arranged in the heading so as to just about break out at the proper section. Sometimes the blast went a little above and sometimes a little below. I remember one or two places in the south heading and one in the north heading where the roof was enlarged considerably to make it safe; but we had no difficulty in regard to the contractor wishing to go outside of the lines. The price given was sufficient to cover his expenses and give him a little profit, but it was not enough to make him wish to go far out of the way.

Mr. Mordecai: With a softer rock you might have found it a difficult matter to keep the contractor within the lines.

Mr. Searles: We had no difficulty of that kind. The settlement with him was always perfectly satisfactory.

Mr. Whitelaw: Speaking of the probability of that depression having been a water course at some time reminds me that in building the old lake tunnel we encountered a sudden change from what appeared to be the glacial clay to a very soft clay, indicating that there had been a channel there, and the change from hard clay carrying boulders to a soft clay was abrupt.

Mr. Searles: I mentioned in the paper meeting a wall of rock. On running out of rock into sand, the rock was almost vertical and we supposed it would go down indefinitely. Had we made a drift at the bottom instead of the top of the tunnel section we should have found that we were mistaken in that supposition.

Mr. Rawson: As I remember, you referred in your former paper to a good deal of gratuitous work the company did for the government.

Mr. Searles: One item was the filling up of the bay. We were com pelled to fill up the entire bay with an embankment averaging about 15 feet in depth in lieu of paying any right of way. There are other items of interest that I may not have mentioned. For instance, the damage done to the post by the blasting operations. The shocks were felt all

over the post. (Shows diagram of officer's quarters and barracks for the cadets.) When we were finishing the south approach large pieces of rock were frequently thrown up and one or two houses were struck. This was afterward prevented by loading with timber. The shocks felt from the blasting were particularly disagreeable in the astronomical department and the gas-works; but it was more an annoyance than anything else. Very good nature was shown. The government had sanctioned the work, and the officers submitted gracefully to the annoyance.

Mr. Rawson: Has any trouble been experienced in the settlement of the arch?

Mr. Searles: There has been no trouble as far as trains are concerned, but the leak has always continued at Station 78. There was an active leakage. I have understood that a portion of the arch has been considered hardly safe within the year. It is feared that the mortar may have disintegrated somewhat by the action of the water, which is entirely free from sediment.

Mr. Whitelaw: Is it a double track tunnel?

Mr. Searles: Yes, 26 feet wide. This section was originally intended for a rock foundation section. Another section was designed and adopted in case an invert should be necessary, which was not used.

Mr. Mordecai: What is the distance to the roof from the top of the rail?

Mr. Searles: Twenty and one-half feet less 1½ would be 19 feet on the centre line.

Mr. Whitelaw: Is there any account of that tunnel in Drinker's work?

Mr. Searles: No account of it has ever been published. It has not been noticed at all.

Mr. Rawson: Is this the only tunnel on the line?

Mr. Searles: There are three others. One at Haverstraw, 1,600 feet long, is built with the same section as the West Point tunnel. It is in solid rock, but shale instead of granite. Another tunnel is 800 feet long, at Newburgh—a tunnel in earth work, but without invert—the walls have wide footings. The third is in solid rock near Little Falls.

LANDSCAPE ENGINEERING.

By John L. Culley, Member Engineers' Club of Cleveland.

[Read February 14, 1888.]

The adornment of public and private grounds is what is known as Landscape Treatment, Landscape Gardening or as Landscape Engineering, and is an art that seeks by the combination of the principles of nature and of art the production of the most beautiful landscape effects. More than nature or art, it is their highest refinement.

Much has been written on this subject, yet its fundamental principles are comparatively few. There are two recognized styles of treatment—the *ancient* or *geometric*, and the *modern* or *natural*. Each style is susceptible of a great variety of modifications, either as a distinctive style, or as combined, the one style more or less with the other.

The oldest known systematic treatment of public and private grounds is the geometric, hence its title to the ancient. It is authoritatively stated that this style was used by the Egyptians more than three thousand years ago. The famous hanging gardens of Babylon were undoubtedly of this style. The sole style throughout Europe for many generations, its distinctive feature was the prevalence of geometric lines, and the regularity of distances between objects, as walks, drives, plantation, etc. Being as old as the art of house-building, the lines of which it was supposed to reflect, and on account of its close alliance to architecture, it was sometimes known as architectural treatment. It is also true, that it was more or less pretentious, according to the development of the national architecture. The lines of the walks and drives were either straight, curved, or a combination of both. Its regularity gave it a mathematical precision void of natural selection, or of the impression of being the work of chance. Thus an object is approached by a straight drive or walk with rows of trees, etc., planted with great regularity, whilst the planting of one side is exactly reproduced on the other. A central walk cuts the garden, with cross walks at regular distances, whilst the formation of sections on one side of the central walk is duplicated on the other.

This style when carried to the extreme becomes, from its monotony, very tiresome.—a most serious objection, for the interest in a treatment should never pall. Nothing could be more absurd than the perversion of trees and shrubs, as is often done by clipping and otherwise, into unnatural objects, as houses, lions, etc. It may, however, be used with good effect in public squares and private grounds of limited dimensions, especially so when modified by modern treatment.

The natural or modern style, aiming at the reproduction of the most refined sentiment of natural scenery, imitates the agreeable forms of Nature. Here pleasure grounds are laid out in flowing lines and forms, surfaces are rounded out and are full, the walks and drives twist and turn at almost every point, trees and shrubs are planted with great care to avoid regularity, in fact, everything bears the impression of natural selection. Hence in contradistinction to the regular geometric, this is called the irregular style. It is also sometimes called the English style of treatment. Mr. J. C. Loudon tells us that the agricultural lands of England were earlier than any other European country inclosed with hedges, producing an appearance resembling a country seat laid out in the geometric style, and hence it was that the attempt to imitate the irregularities of Nature in the adornment of pleasure grounds was made in that country earlier than in any other part of the world.

To compare this style with the geometric it may be said that whilst the geometric harmonizes with the forms of art, the natural imitates or assimilates the forms of Nature, and is in contrast with architecture. The geometric is perhaps more adapted to small surfaces, whilst the natural is the only style that can with good effect be applied to larger ones. Frequently the effect of natural is heightened by a sparing use of the geometric. Thus in large estates the immediate neighborhood of the house is sometimes treated with geometric flower-beds, terraced elevations, etc., whilst the great expanse of the estate is laid out in the irregular style.

Even in a broad natural treatment a few well selected geometric drives and walks can be employed with good effect.

It is interesting to note the origin of these two styles of treatment. Thus when the world was one expanse of natural scenery man naturally sought diversion in pleasure grounds planned after the architecture of his age. But when the surface of the earth became covered with rectangular fields, he found pleasure in natural adornment. Thus to one, who has spent his life in untrammeled nature, the right lines of cultivated lands give pleasure. The converse of this rule is equally true. Hence it is that the treatment of pleasure grounds should not be too natural, nor contain too many geometric lines. The treatment should always possess certain salient qualities that please, interest, instruct and charm the beholder.

The general effects of all styles are designated as the *beautiful* and the *picturesque*, or by synonymous terms. The effect produced by flowing outlines, softness of surfaces and by fully developed growths is known as the beautiful. The picturesque is produced by spirited outlines, indicative of power, by wild or bold characters, and by broken surfaces. In refined treatment the beautiful is supposed to predominate, whilst the picturesque gives it a charming variety.

Good taste dictates that the treatment should have: *Unity* in the general plan, or a wholeness of production and balance of proportion pleasing to the eye; *variety* enough to arouse the curiosity, and give a lively interest to every detail; and *harmony* preventing discord, by blending the unity of the whole with the variety of detail. Above all, it should have an intelligent expression indicating a purpose for, or meaning to, every embellishment; or, as Mr. Loudon expressed it, the creations of this art are intended to please the mind through the eye, and satisfy the reason, the essential qualities of the art being to create and to please. Such in brief are the fundamental principles of landscape treatment as laid down by the authorities.

William Kent, the father of the modern school, was the first to vindicate the natural against the artificial, and banish the monstrosities of clipped trees and shrubs, and of absurd conventionalities. It is related of him that he even went so far as to introduce dead trees into his treatment. Born in Yorkshire, England, in 1685, he lived until 1748. Kent was followed by Humphrey Repton, 1753 to 1818, the author of "Hints on Landscape Gardening" (1795), and of other professional works. The two great authors, however, are J. C. Loudon, of England, 1783 to 1843, and the American A. J. Downing, 1815 to 1852. Both were profuse writers, each being the author of many valuable works. Loudon's "Suburban Gardens" and Downing's "Landscape Gardening and Rural Architecture" are each highly recommended. Kemp's "How to Lay Out a Garden" and Scott's "Suburban Homes" are excellent works. The dissertations of these authorities on architecture are, at the present date, somewhat stale. It may also be remarked that their sweet panegyrics on the beautiful in nature, are tiresome. Yet it is a fact that scarcely anything has been added to the art of laying out a landscape since the days of Downing and Loudon—so thoroughly and masterly did they treat this subject.

All writers refer to landscape treatment as *gardening*, the *garden* being the whole subject treated, whilst within his province the professional gardener was engineer, architect, planter and gardener. In these days of modern division of labor, pretentious structures are consigned to the professional architect, the planting to a skilled gardener, whilst the civil engineer, by whatever name called, conducts the improvements in chief —a knowledge of engineering being of the first importance in the conception and execution of a landscape design of any magnitude. The landscape engineer should have a sufficient knowledge of architecture to know that the designs are in good taste; to design and execute the lighter architectural parts. and to properly locate all structures. He should also have a thorough knowledge of trees, shrubs and plants and of the art of grouping them. The term *gardening*, as applied to this art, should be regarded as obsolete. The better and more appropriate term at the head of this article should be used in its place.

First in the practical application of this art comes the survey. As upon the accuracy of the survey depends the degree of certainty and rapidity with which the future plans can be reproduced on the ground, it is important that close measurements be taken with a steel tape of all objects and features that in any way will be useful in the study of the landscape. Accuracy of measurement is of more importance than a record of level contours. Frequently a successful treatment may be made without a single elevation being taken. It is wise to measure carefully both in plan and in elevation those parts requiring close study. Nothing, however, could be more foolish, both as to the waste of time and of energy, than the practice, as it is sometimes pursued, of staking, measuring and leveling cross-section squares of small dimensions, especially so on perfectly level ground. Broken, irregular surfaces require careful leveling, so that when platted you have its complete expression. Rather than resort to small square cross-sections, it has been found more convenient to select base lines from which at regular distances cross-sections are taken at such points on the broken surfaces where elevations are desired, whilst a convenient number of elevations are taken on the evener surfaces. It is only by accident in the regular square system that its points coincide with elevations needed. Besides securing just the needed elevations, the base lines on the plans become useful in reproducing the design upon the ground.

Upon a plan sufficiently large to show all the parts of the landscape is worked out the style of treatment, the location of walks, drives, trees and shrubs, buildings, and, in fact, everything pertaining to the execution of the design and of its elaboration. No attempt at execution should be made until the plan has been thoroughly worked out and definitely decided upon. Conveniently located base lines are then drawn upon the plan, and the scaled distances of the lines of treatment from these base lines, generally right-angled ordinates, measured. By this method the lines of the plan are reproduced on the ground.

A short paper can, of course, cover only in a general way the varied duties and requirements of a landscaper in the execution of a design. The first thing that engages his attention is a proper system of deep drainages, both for the convenience of animal life, the propagation of

the vegetable, and for the protection of his creations. Then there is the location and execution of drives and walks of proper grade and drainage. Road making is a subject that demands close attention. Then comes the formation of the surface into slopes, mounds, valleys, etc.; the disposition of the earth, the soil, and of manures and fertilizers, and the production of lawns from seed or from sod, as well as their care and preservation. Works of art in good taste and of permanent character require the display of no small amount of ingenuity. When, where and how to plant tress, shrubs and flowers are interesting subjects. The pleasing effect of a treatment is due more to the manner of grouping trees and shrubs than to anything else. These and many other things require much more notice than can now be given them.

Amongst the leading landscapers of this country may be mentioned Fred. Law Olmstead, R. Vaux and S. Parsons, of New York; Charles Miller, of Philadelphia; George H. Brown, of Washington, D. C.; Joseph Earnshaw, of Cincinnati, and E. W. Bowditch, of Boston; each of whom has devised and executed most charming landscapes. Of the foreign landscapers, Major Andre, of Paris, and M. Gibson, of England, seem to be prominent.

This is, perhaps, the only branch of engineering devoted to the creation of the beautiful. Useful results only are the objects of construction in all other branches. This seeks the useful with a high regard for the beautiful. To succeed in it the civil engineer should have a natural aptitude for it, a familiarity with its literature and all the latest processes of landscape treatment, ornamentation and embellishment, and a thorough mastery of that constructive art whose creation pleases the highest qualities of the mind whilst satisfying our needs. To avoid costly experiments, his creations should be seen as clearly in the imagination as they afterwards appear in reality. He should have a knowledge of horticulture and of botany. His development will come with experience.

FARM POND CONDUIT—BOSTON WATER-WORKS.

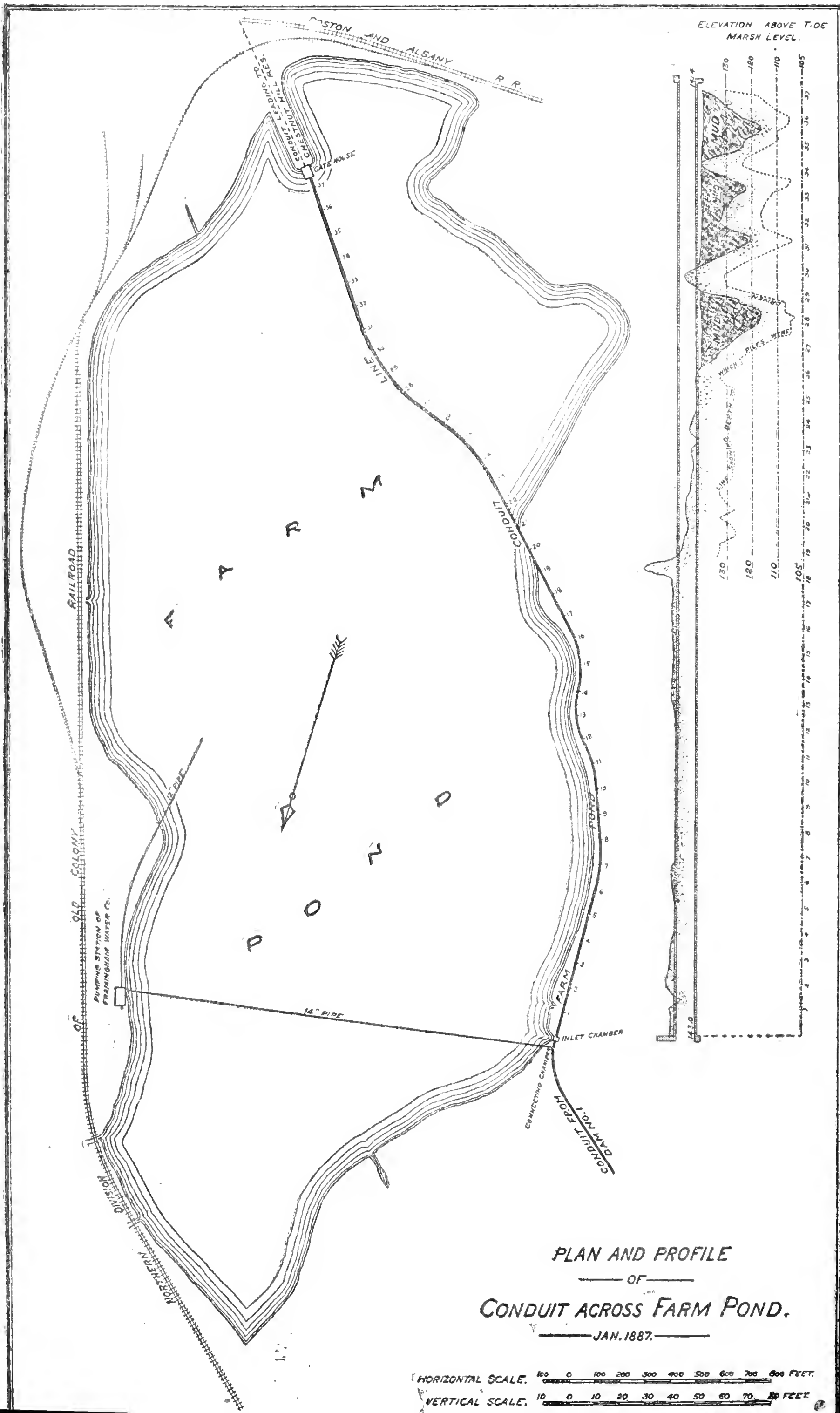
By Henry H. Carter, Member of the Boston Society of Civil Engineers.

[Read October 17, 1888.]

Farm Pond Conduit, which forms part of the Sudbury River waterworks, was constructed for the purpose of conveying the water from the storage reservoirs on the Sudbury River, across Farm Pond to the main conduit leading to Chestnut Hill reservoir.

The original scheme of the Sudbury River works contemplated the use of Farm Pond as an auxiliary storage reservoir, and the conduit from Basin No. 1 (which is the lowest basin on the river) was only built as far as the upper end of Farm Pond. The main conduit leading to Chestnut Hill was located at the other end of the pond, which thus acted as a storage and settling basin for the Sudbury River water.

The pond has an area of about 165 acres, and its ordinary level is 149.25 feet above B. W. W. base. It is situated in the village of South Framingham, alongside the Boston & Albany Railroad, and in close proximity to numerous manufactories and dwellings.



PLAN AND PROFILE
OF
CONDUIT ACROSS FARM POND.
JAN. 1887.

FARM POND CONDUIT.

JAN. 1887.

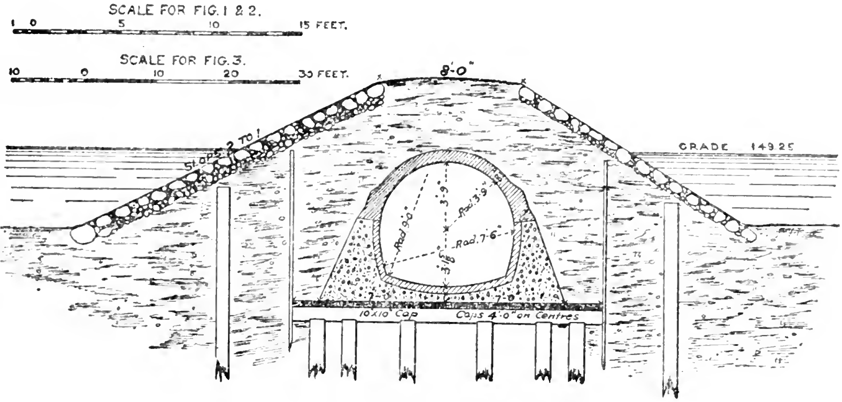


FIG. 1.

SECTION OF CONDUIT ACROSS POND
ON PILE FOUNDATION.

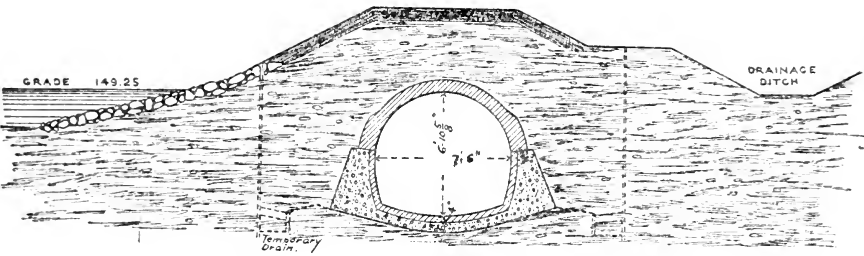


FIG. 2.

SECTION OF CONDUIT ON SHORE.

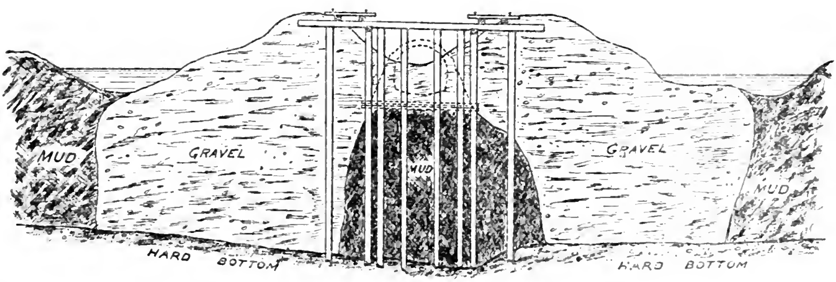


FIG. 3.

SECTION AT STATION 31 + 25.
SHOWING RAILROAD TRESTLE AND GRAVEL FILLING.

In order to preserve the purity of the water in the pond and prevent the entrance of objectionable drainage and surface water, it was originally proposed to divert the tributaries of the pond.

A ditch was constructed along the west and south shores, which intercepted the drainage from cultivated fields in the vicinity and conveyed it into the Sudbury River below the water-works reservoirs

A sewer was also projected to intercept the drainage from the east side of the pond; this sewer was never built, owing to difficulties in securing a right of way. The sewage from a large straw shop and from numerous dwellings was allowed to enter the pond and create a nuisance in the vicinity of the gate house at the entrance of the main conduit. For the first few years after the completion of the Sudbury River works, it was believed that the water from the storage reservoirs was purified by its passage through the pond; the yellow color of the water, which was noticeable in the reservoir, being lost after passing through the pond.

The drainage and sewage from South Framingham, in the course of time, however, commenced to have an injurious effect on the quality of the water.

In October, 1881, the well-known cucumber taste appeared in the water of the Sudbury River supply. The water in the upper reservoirs was comparatively pure and free from taste, and the trouble was found to originate in Farm Pond. In order to prevent the water in the reservoirs from being contaminated by mixing with the Farm Pond water, the pond was drained down to grade 140 and a temporary ditch was constructed around the shore, through which water from the reservoirs was sent to the city.

This temporary ditch served for the short time that the pond water was unfit to use: but as the trouble was liable to occur at any time, and as the residents of the village objected to the lowering of the water in the pond, it was determined to build a permanent masonry conduit connecting the inlet chamber with the gate chamber.

The distance between the upper and lower gate chamber was 3,760 feet. For a distance of 2,100 feet the conduit would naturally be located on the shore of the pond; for the remaining distance, however, it was necessary to cross the pond, and the construction of a permanent conduit presented many difficulties. The water in the pond, as has been previously mentioned, stands at grade 149.25. The bottom of the pond (except where a small gravel island is situated) is about grade 140. The bottom is composed of a very soft mud, varying in depth from 1 to 30 feet. Underlying this mud (where the mud was the deepest) was a stratum of quicksand, in some cases 15 feet in depth. The general character of this mud and quicksand was such that a solid steel rod could be worked down 55 feet in the deep holes with comparative ease. To obtain a firm and unyielding foundation for the conduit under the circumstances required considerable study.

The plan finally adopted was to drive piles throughout the mud portion of the pond, and to fill around the piles with gravel in such a manner that the mud should be displaced by the gravel and the piles prevented from moving laterally. The gravel was then excavated between

the piles down to the proper grade, the piles sawed off and capped, a timber platform placed on the capping, and the masonry structure built on the platform.

Soundings were made over that portion of the pond where the conduit would probably be located. These soundings showed the grade of the top of the mud, and also the grade of the hard bottom underlying the mud. From the plan and cross sections thus obtained the location of the conduit was determined. In order to take advantage of the minimum depth of mud, the line of the conduit is curved through the greater part of its length. A slight deviation from the located line in several instances would make a difference of 10 feet in thickness of the mud. Having determined the location of the conduit line through the pond and the general character of the work, a contract was made in November, 1883, to drive the piles and construct the timber trestle, from which the gravel could be dumped to displace the mud. The description of the timber trestle is as follows: The bents are composed of ten piles spaced 4 feet apart, capped by a spruce timber 10 inches square and 35 feet long, notched down 2 inches on each pile. On the caps are laid the 8 inch by 10-inch stringers, which form a support for railroad ties.

As the piles for the support of the trestle were ultimately to form the foundation for the conduit, great care was exercised in driving them. The inspector on the work kept a careful record of

1st. The number of the pile: so that it could be identified on the ground and on the plan at any time.

2d. Its length.

3d. The grade at which it first met the mud.

4th. The grade at which hard bottom underlying the mud was encountered.

5th. The grade of the bottom of the pile after it had been driven.

6th. Distance which the pile penetrated in the last three blows.

7th. Fall of hammer on last three blows.

The inspector was provided with a book, which showed the soundings made every 25 feet along the centre line of the conduit; also soundings made right and left of the centre line on distances corresponding to the outside piles. This record of soundings was of assistance in determining the length of piles required in any particular location. No trouble was apprehended in getting a sufficiently hard bottom to sustain the weight of the superincumbent masonry, but fears were entertained as to the ability of the piles to sustain a lateral thrust in the deep portions of the pond, when the filling should be dumped in around them. In order to resist this lateral pressure as much as possible, precautions were taken to drive the piles as far as practicable into the so-called hard bottom, even if hard strata should be encountered after driving through the mud. In general the orders given to the inspector were to drive 12 feet into the hard bottom. In some cases it was found impossible to reach this depth without shattering the piles, but the greater part of the piles reached this depth.

The piles were driven by means of floating pile drivers supported on a raft made of timbers and empty oil barrels. The location of the centre line of the conduit, as has been previously mentioned, was determined

from the plan which showed the relative depths of hard bottom as indicated by the borings. These borings were made in winter on the ice from a base line run out from the lower gate chamber. As this base line could not be produced in summer, it was necessary to locate the conduit line by triangulation from a traverse made around the shore of the pond. Until a sufficient number of piles had been driven on which to locate ranges it was necessary to depend on range sights located on the shore, in some instances a quarter of a mile from the pile driver. The location traverse was run with great accuracy, and when the piles were all driven and the closing angles and distances could be measured. it was found that the angles closed to a few seconds and the distance to a few hundredths of a foot.

The soundings made on the conduit location gave an exact indication of the character of the bottom. Any peculiarity in the driving of a pile was referred immediately to the profile showing the strata. From the knowledge of the strata through which the pile was being driven a study could be made of the action of piles driven in quicksand, gravel, mud, hard pan, etc.

Of the 3,750 piles driven, 318 were noted as driving very hard, that is, a distance of from 0 to 3 inches in the last three blows, with about 12 feet fall of hammer: 950 were noted as driving hard, that is, a distance of from 4 to 8 inches in the last three blows; 2,016 were noted as driving medium, or a distance of from 9 to 12 inches in the last three blows, and 141 were noted as driving easy, or a distance of over 12 inches in the last three blows.

Record sheets were made showing the number and location of every pile, and by referring to the record book the exact history of the pile could be determined. A reference to the boring sheets at the station where the pile was located would indicate depth of water and mud and character of strata through which the pile had passed. Considerable difficulty was experienced by the contractor in procuring piles of the required length ; and on several occasions work was suspended pending the arrival of suitable piles. On April 9, five months after the driving of the first pile, the contract was completed. In order to afford free communication between the two sides of the pond two wooden culverts were designed, and the necessary pile work and sheet piling were performed under the first contract. Considerable difficulty was experienced in finding a suitable location for the culverts. On one hand, if the culverts were located on the gravel island it would be impossible to accurately drive the 4-inch tongued and grooved sheeting into the hard gravel of which the island was composed. On the other hand, if the culverts were located where there was a considerable depth of mud and where a good job could be made of the driving, it was feared that the unequal pressure caused by the gravel filling outside of the culvert would destroy the culvert. The culverts were finally located where a depth of about five feet of mud, underlaid by a bed of quicksand, was located, and no trouble was experienced in getting a tight job on the sheet piling.

The average length of the 3,750 piles driven on the work was 37 feet : 112 piles over 50 feet long, and 827 over 45 feet long were driven.

CONSTRUCTION ACCOUNT

OF THE PILE AND TIMBER WORK IN FARM POND

LABOR	Making Floats and Sheeting Driver			Loading and Transporting Piles			Transporting Timber			Pile Driving			Caps and Stringers			Sheet Piling			Placing Ties			Miscellaneous		
	Days Work	Rate	Amount	Days Work	Rate	Amount	Days Work	Rate	Amount	Days Work	Rate	Amount	Days Work	Rate	Amount	Days Work	Rate	Amount	Days Work	Rate	Amount			
FOREMAN	7	$3 25	$22 75		$	$		$	$	82	3 25	$266 50	16	$3 25	52 00	16	$3 25	$52 00		$	$		$	$
FOREMAN		$		96¼	2 00	192 50	19	2 00	38 00	118½ 95	3 00 2 50	355 50 237 50	20	2 50	50 00							3¾	3.00	11 25
ENGINEMAN	7	$3 25	22 75							87	3 25	282 75				16	3 25	52 00						
ENGINEMAN		$								103½	2 50	258 75												
TOPMAN		$								166 17	2 00 1 75	332 00 29 75				16	2 00	32 00						
DECKHAND		$								116½ 255½	2 25 2 00	262 12 510 50				16	2 00	32 00						
DECKHAND		$								280	1 75	490 00				40¾	1 75	71 31						
LABORER		$		449	1 75	785 75	89	1 75	155 75	20	1 00	20 00												
LABORER	15	$1 75	26 25				4	1 50	6 00										4½	1 00	4 50	29	2 00	58 00
CARPENTER	14	$2 25	31 50							177	2 25	398 25	60	2 25	135 00	32	2 00	64 00	6	1 50	9 00			
CARPENTER	18	$2 00	36 00							172	2 00	344 00	58	2 00	116 00				51¾	2 00	103 50			
HORSE		$		104¾	1 50	157 12	20	1 50	30 00															
MATERIALS		Gins Floats	124 00 314 95																					
TOTAL			$578 20			$1135 37			$229 75			$3787 62			$353 00			$303 31			$117 00			$69 25
MATERIALS	VALUE																							
PILES	$.0614 per foot									3638 piles		8221 88												
SPRUCE caps and stringers	$16.10 per M ft BM 13.50 " "												159 M 12 M		2659 90 162 00	Wales 12 M		19 20						
SPRUCE plank and braces	$14. " "									1102 M braces		154 28	3.6 M plank		50 40									
SPRUCE ties	$14. " "																		24.18 M		338 52			
IRON BOLTS	$2¾¢ 3¢ pound												10480 lbs 3830 "		283 23 114 90									
IRON SPIKES	$.03 " "									Spikes in braces 872 lbs		26 16	88 lbs		2 64	205		6 15	540 lbs		16 20			10 00
SHEET PILING	$18.60 M ft BM															25.5 M		474 30				Shanty		30 00
MISCELLANEOUS				Sleds		3 50	Sleds		1 50	Freight on pile drivers		75 00	Building derricks		5 00							Employees RR fares		10 00
TOTAL						$3 50			$1 50			$8477 32			$3178 07			$499 65			$354 72			$50 00
PLANT																								
PILE DRIVER	$1.50 per day									180 days		270 00												
PILE DRIVER	$1.40 per day															16 days		22 40						
COAL	$6.40 per ton									35 tons		224 00				3 tons		19 20						
OIL, WASTE, &c												22 00												
Loss of TOOLS and interest on value												120 00			28 50									
TOTAL						$			$			$636 00			$28 50			$41 60			$			$
GRAND TOTAL						$1138 87			$231 25			$12900 94			$3559 57			$844 56			$471 72			$119 25

PILE DRIVING

COST			VALUE AS SHOWN ON ESTIMATE	PROFIT
COLUMN	1	$578.20		
"	2	1138.87		
"	4	12900 94		
"	8	60.00		
		$14678 01	$16344.00	$1665.99

TRACK WORK

COLUMN	3	$231.25		
"	5	3559 57		
"	8	30 00		
		$3820.82	$7316 24	$3495 42

TIES

COLUMN	7	$471.72		
	8	10.00		
		$481.72	$719.36.	$237 64

SHEET PILING

COLUMN	6	844.56		
"	8	19.25		
		$863.81	$1674.75	$810 94
				$8209.99 TOTAL PROFIT

COST OF DRIVING 1 PILE $4.05
CONTRACT PRICE 4.50
PROFIT $.45

COST OF 1 FT. OF TRACK $1.12
CONTRACT PRICE 2.15
PROFIT $1.03

COST OF LAYING 1 TIE $.213
CONTRACT PRICE .32
PROFIT $.107

COST OF 1 FT Sheet Piling $2.83
CONTRACT PRICE 5.50
PROFIT $2.67

A careful record of the piles noted as driving easy was made, so that if opportunity afforded, during the construction of the conduit, they might be tested.

On referring to the boring sheet many piles, which were noted as driving over 12 or 15 inches in the last three blows, were found to have their ends resting in quicksand, whereas a few feet more driving would have brought them up solid in a gravel strata. All such cases were noted and sheets prepared for the further driving of such piles as were marked unsatisfactory.

Levels were taken on nails driven along the trestle, to see if the jar of the gravel trains would settle the piles in the quicksand bottom. These levels were taken periodically for about 6 months, but no settlement was perceptible.

A detailed account was kept of the expense incurred by the contractor in the prosecution of the work, and this expense was divided among the separate items on which the bid was based, in order to see the profit or loss on each item.

FILLING.

The original intention was to complete the whole conduit in two working seasons. On this account the contract for filling was let before the trestle was completed, and filling was started from the completed portion of the trestle on March 13, 1884. The gravel was transported from a bank located about three-quarters of a mile from the middle of the trestle, near the upper inlet chamber. The contractor's plant consisted of a steam shovel, two locomotives and thirty dump cars. A double line of railroad track was laid on the trestle on the ties which had been placed under the previous contract. Fifty thousand cubic yards of gravel were advertised for, and the contract was awarded at $0.47 per cubic yard.

The amount of gravel that would be required to fill the pond was necessarily a matter of guess work.

The extent to which the gravel would displace the mud in the deep parts of the pond and the slopes which the gravel would take in the mud were also matters of guess work. As some assumption had to be made in order to get an approximate quantity, the following theoretical section was adopted: The bank was taken as 10 feet wide at grade 153.5, with 2 to 1 slopes down to grade 145. At this elevation a level berm 5 feet wide was assumed and then a 3 to 1 slope continued to grade 140, the top of the mud. From grade 140 to 135, or in the first 5 feet of mud, the filling was assumed to take a 1½ to 1 slope, and then a 1 to 1 slope the rest of the way. This section gave as a result the quantity of 60,000 cubic yards as the amount to be deposited in the pond. As this result seemed excessive, it was deemed best to advertise for 50,000 cubic yards only, but the first estimate proved nearer the truth, as 59,000 cubic yards were actually deposited.

The linear distance of trestle to be filled was about 1,700 feet. Of this amount 625 feet was a shallow fill in water averaging about five feet deep and on a hard sand and gravel bottom. The manner of filling this 625 feet was immaterial, as there was no mud to displace, and the piles

were firmly driven into the sand and gravel and could not be moved sideways.

The amount of gravel necessary to make the conduit embankment on the hard and shallow bottom of the pond after the masonry was completed was calculated, and from the known capacity of the gravel cars a sufficient number of cars were dumped each side of the trestle.

The muddy and deep portion of the pond presented greater difficulties, and great precautions were taken to insure the successful filling in these portions of the pond.

A line of board sights about 6 inches wide and 5 feet high was nailed along the trestle. The sights were placed 25 feet apart, painted alternately black and white, and accurately set to line with a transit. As the conduit line was curved, a broken line of sights was necessary in order to allow of their being placed on the trestle. The points from which observation on the sights were to be taken were located on the gravel island, and on the shore, where no movement of the trestle was possible. By means of these sights the slightest movement could be detected by the eye, and the dumping of gravel changed in accordance with the warning given by the sights.

The inspector was furnished with a profile showing the elevation of the top of the mud, and also of hard bottom. He also had a rolled cross section sheet showing the cross section of the mud every 25 feet; these cross sections extended 60 feet right and left of the centre line, which was as far as the filling was thought liable to extend.

As previously mentioned an assumed theoretical section of the way the filling would displace the mud was drawn: from the known quantity of filling between each assumed 25-foot section and the known capacity of the dump cars: a schedule was drawn up showing the number of times that a train should be dumped between given sections. It would seem at first that a schedule of the number of train loads to be dumped in a section whose contents had been determined from an assumed position of the filling and mud would be very approximate.

The principal use, however, to be made of the schedule was to have a record of just where the trains dumped, and to be able to compare the actual with the theoretical amount.

For instance, suppose that the schedule required the train to dump 113 times on the left and 65 times on the right between station 27 + 50 and 27 + 75. If the gravel showed up above the water after 20 trains only had been dumped on the right instead of the 113 called for, it showed that the mud had not been displaced, and more material was dumped, even if it involved shoveling it up on to a bank. In one instance, beween stations 31 + 0 and 31 + 25, the schedule called for 146 dumps. After about 30 dumps the filling showed above the water. Filling was continued until the gravel was about 6 feet above the water. On the next dump a slide took place and the top of the filling could just be touched with a 17-foot pole. These slides forced up extensive islands of mud from 50 to 150 feet distant from the trestle. On the completion of the work it was found that the actual number of times the train dumped, closely corresponded with the schedule. From station 26 to station 30 in the first deep hole, the average difference in

the actual and scheduled dumps was about seven dumps. Considering the fact that in some cases the scheduled amount was over one hundred loads the correspondence is close.

The line of sights was of great assistance in keeping the trestle on line. A heavy slide, such as the one mentioned above, would perhaps move the trestle off line in that particular spot 6 or 7 inches. This movement was instantly apparent by the bowed condition of the line of sights.

Notwithstanding the precaution and care taken in filling, a lateral movement of the trestle took place. In the first deep hole between Station 26 and Station 30 a gradual movement towards the northeast occurred. This movement took place shortly after the first filling was put in. The mud in this cove was considerably deeper on the northeast side, and the filling evidently moved down hill, sliding along the hard bottom. Although the filling was changed to the northeast side of the trestle as soon as the movement was discovered, it proved to be impossible to force the trestle back on to line. Observations with a transit on the line of sight showed that the trestle slowly worked towards the northeast even after the filling was completed. The rate at which the trestle moved decreased rapidly in the course of time, and after fifteen months no further movement could be detected. The maximum variance from the true line was seven inches in the middle of the deep hole, running out to nothing on the end.

In the second hole it was found possible to move the trestle back and forth in accordance with the method of filling.

When the filling was completed the trestle was nearly in its true position, and no further movement was detected during the fifteen months that the observations were continued.

It should have been mentioned that almost all the filling was dumped outside the trestle ; that is, all the dump cars were placed so as to dump away from the centre of the trestle. In this way it was believed that a pocket of mud would be enclosed between the two heaps of filling ; this pocket of mud could do no harm and filling would be saved. The double piles on the outside of the trestle were so close together that they acted like a retaining wall for some time. A tremendous pressure was exerted against these piles, and before the completion of the filling some of them had buckled to such an extent that it was feared they would give way. Filling in the middle was resorted to at the worst places in order to make an earth brace to hold the piles apart. Temporary pile braces were also wedged against the double piles to secure them.

The filling of the trestle was completed on June 11, 1884, 59,000 cubic yards having been deposited in place. Throughout the following winter borings were made through the gravel to determine the exact position and slope assumed. After the completion of the filling, it was observed that in the deep cove between station 26 and station 30, that groups of ten or twelve piles in adjoining bents were actually settling away from the caps. The cap would be held in its original position perhaps, by two or three piles in the bent, and the remainder of the piles in the bent dropped down by their own weight from one-quarter to three-quarters of an inch. One pile in this locality slowly settled away from the cap to the extent of 5 inches, drawing the iron bolt with

Construction Account of the Filling in the Farm Pond

Labor	Trackwork Days Work	Trackwork Rate	Trackwork Amount	Loading Days Work	Loading Rate	Loading Amount	Transporting Days Work	Transporting Rate	Transporting Amount	Dumping Days Work	Dumping Rate	Dumping Amount	Miscellaneous Days Work	Miscellaneous Rate	Miscellaneous Amount
Superintendent													60	$6.00	360 00
Foreman	10	4.00	40 00	100	$4.00	400 00	10	$4.00	40 00				12	4.00	48 00
Foreman	95	$2.00	$190 00							32	$2.00	$64 00			
Engineman				122	4.00	488 00							10	4.00	40 00
Craneman				122	3.50	427 00							10	4.00	40 00
Engine Driver							229	2.50	572 50						
Fireman				123	1.75	215 25	216	1.75	378 00						
Brakeman							105	1.50	157 50						
Blacksmith	125	2.00	250 00										128	2.50	320 00
Laborer	638	1.50	957 00	574	1.50	861 00				490	1.50	735 00	105	1.50	157 50
Ice Cutter							15	1.50	$22 50						
Total			$1437 00			$2391 25			$1170 50			$799 00			$965 50
Plant															
City Steam Shovel	$9.00 per day			51	$9.00 Repairs	$459 00 110 20									
Engine and Cars	$7.00 per day for each train.						235	$7.00	$1645 00						
Steam Shovel	$13.00 per day.			75	13.00	975 00									
Coal	$6.00 per ton.			Tons 75	6.00	450 00	Tons 120	6.00	720 00				Tons 5 at 6.00		$30 00
Oil and Waste						136 00			104 00						
Blacksmith Shop															125 00
Transportation of Plant															1500 00
Loss of Tools and Interest on Value			$50 00									5 00			150 00
Loss on Rails Ties &c.															500 00
Blacksmiths Supplies.															150 00
Total.			$50 00			$2130 20			$2469 00			$5 00			$2455 00
Grand Total			$1487 00			$4521 45			$3639 50			$804 00			$3420 00

No. of cubic yards of material 59010.
Material – Fine Gravel and Sand
Average Haul 3700 ft.

Cost to load
Column 2 $4521.45
43 per cent Column 5 1470.82
$5992.27 — 10 cts. per yard.

Cost to transport
Column 1 $1487.00
Column 3 3639.50
49 per cent Column 5 1676.04
$6802.54 — 12 cts. per yard.

Cost to dump
Column 4 $804.00
8 per cent Column 5 273.64
$1077.64 — 2 cts. per yard.

24 cts. per yard total cost.

Bank measurement.

Small Shovel averaged 300 cu. yds. per day
Large Shovel averaged 582 " " " "
The above includes time employed in setting up, shifting, &c.

Plant Used.

1 Steam Shovel
2 Locomotives
14 Cars holding 2.5 yds. each } car measure.
16 Cars holding 1.85 yds. each }
6700 lin. ft. track 35 lbs. per yd.

1 cubic yard in bank made 1.16 cubic yard in car.

it. These occurences gave cause to fear that the piles would settle when the masonry conduit was built on them. No reason for this settlement could be discovered in the pile record book, as the piles were over 45 feet long and noted as driving fairly hard. The boring record showed that the mud was very deep at the above localities and was underlaid by a bed of quicksand. These piles were tested about 12 months after they were driven, during the construction of the masonry conduit, and although they had apparently settled by their own weight, it was found impossible to move them with a 1,500-pound hammer. It is probable that a slow movement of the quicksand in which the bottom of the piles rested took place from the great weight of the superincumbent filling, and that this movement changed the position of the piles to such an extent that they were drawn away from the caps.

A force account is appended showing the cost of the work.

MASONRY.

On August 14, 1884, bids were opened for the construction of the masonry conduit. The bids ranged from $68,000 to $127,000. Although it was evident that the work could not be done for the lowest figure, the contract was so awarded, and work was commenced at the upper inlet chamber on August 23, 1884. The general section of conduit built on the shore is shown by the drawing.

The character of the material found in the shore trench was very variable. The greater part of the conduit is built on a hard, coarse sand and gravel bottom. For a length of several hundred feet quicksand was encountered in the foundation, and in the vicinity of where the conduit starts to cross the pond, stiff sandy clay was met with. A light plank platform was adopted wherever the sand was of such character that it flowed and would not stand on a slope. Where the sand was mixed with gravel, or where clay was encountered, the platform was abandoned and the concrete placed directly on the soil.

The trench was excavated to about grade 141, or 8 feet below the level of water in the pond.

A large quantity of water flowed into the trench in some places, but it was noticeable that most of the water leaking into the trench came from the side furthest from the pond.

No special difficulty was encountered in the prosecution of the work on the shore section. The points especially insisted on for performance by the contractor were as follows:

1st. All water was pumped from sumps located ahead of the masonry. No underdrainage was permitted by which a drain pipe would be left under the completed masonry. Such a pipe, while it could cause no trouble in a gravel or clay bottom, might be the source of settlement in a quicksand bottom.

2d. No backfilling was permitted to be placed behind the concrete side walls until twenty-four hours after the brick side lining had been laid. Although the concrete side wall alone was strong enough to sustain the pressure of the back filling, it was found that unless the brick lining was laid and set, water would be forced through the concrete and the brick work could not be got in dry.

3d. All the sheeting was drawn before the centres were struck. By this proceeding the arch was supported on the centres while the back filling was moving into the vacancies left by the withdrawal of the sheet plank.

4th. The centres were not allowed to be struck until the back filling had reached at least the height of the crown of the conduit. It was found that no settlement of the arch took place, even when freshly laid, provided the back filling was as high as the crown.

Frequently a large gang of men would be set back filling a length of arch freshly laid. In perhaps thirty minutes the back filling reached the specified height and the centres were struck. No settlement took place even in these extreme cases.

5th. Further loading of the arch after it had been covered one foot in depth was prohibited until the masonry had been laid a week.

6th. All back filling was thoroughly puddled as the material was thrown into place.

By the careful observance of the foregoing directions the conduit was built and on completion showed neither crack, leak, nor settlement of either invert or arch. Diagrams showing the actual shape of the conduit were taken every 25 feet. These diagrams show the actual divergence of the arch from a true semicircle and were remarkably free from the usual depression on top indicating a settlement of the arch.

But 522 feet of the conduit on shore was completed November 25, 1884, on which date work was suspended for the season.

During the winter periodical observations were made of the movement of the trestle. After August 15, 1885, no further movement was discernable.

In April, 1885, the work on the shore portion was recommenced, and was completed in August.

In September the contract was virtually abandoned by the contractor, as he found it impossible to do the work at the contract price. By special agreement with the Water Board, whereby some of the retained collateral was advanced to the contractors, work was again commenced after about a week's delay on the pond section.

The distortion of the bolsters and buckling of the double piles seemed to indicate that an immense pressure was exerted by the filling, and that on taking off the caps the piles would be forced into the centre of the trench.

This idea proved to be erroneous, as the filling had taken a stable position during the summer. It was also expected, from the known position of the gravel filling, that on excavating the gravel from the middle of the trestle that the filling on the sides would tend to force up mud in the centre. This occurred in two places, but no trouble was experienced on the greater portion of the work.

The first operation in excavating the trench in the pond was to saw off the caps on each side where the sheeting of the trench would come. The middle portion of the cap was then pried off, the sheeting driven and the mud and gravel excavated from between the piles. The piles were capped at the proper grade by one of the 10-inch by 10-inch sticks, which had previously been ripped off. The caps were turned on their sides and

notched 2 inches to fit the piles, as the old notches would not fit the piles at the bottom of the trench.

The double piles were sawed off 6 inches lower than the others, and a short bolster placed on the piles. The cap was then notched over the bolster.

The caps were then covered with 4-inch spruce timber run lengthwise of the trench. These timbers broke joint and were fastened to the caps by 8-inch cut spikes. The caps were fastened to the piles by 16-inch oak treenails.

The concrete bottom, up to the level of the invert skewback, was then laid on the platform, and after it was sufficiently set, the forms for the concrete side wall were put in and the concrete put in place. From twelve to twenty-four hours after the side walls were laid the wooden forms were knocked out, as the concrete was then hard enough to keep its shape. From twenty-four to thirty-six hours after the side walls were laid the masons were permitted to line the bottom and sides with brick work. The side walls were back filled as soon as the mortar was set and centres were placed for the brick arch. The arch was back.

filled about one foot above the crown when the centres were struck.

No special difficulty was encountered in building the portion through the pond. During this portion of the work the pond was lowered to grade 145. The average grade at which the piles were cut to receive the caps was 138, so that about 7 feet head of water existed outside of the trench. The leakage into the trench was handled at first by two pulsometers, which finally proved inadequate, and a 6-inch Andrews pump, run by a Hoadley engine, was added.

As some additional pile driving was necessary, an opportunity was afforded to test the piles which the records showed to be unsatisfactorily driven. In all cases it was found that the piles, which had driven easily before, and which had gone in some cases 18 inches or 2 feet in the last three blows, could hardly be moved. Some few were driven to a lower grade, but most of them were dropped on with a fall of about 10 feet of hammer, and if they did not start at the first blow the driving was suspended.

Shortly after laying the concrete side wall hair cracks made their appearance in the concrete masonry. These cracks caused some alarm at first, as they were thought to indicate a lateral movement of the piles in the foundation. These cracks were carefully located, and never made their appearance in the brick masonry. It is probable that these cracks were produced by the weight of the concrete slightly buckling the four-inch timber platform, as in some instances the bents were more than four feet apart.

In December, 1885, the contractor abandoned the work, which was finished by day labor in the following spring. The actual cost of the conduit was $158,000 and the original estimate was $160,000.

The earth embankment over the conduit in the pond was made 8 feet wide on top, with 2 to 1 slopes. The slopes extended down to grade 145, at which grade a level berm was produced by shoveling off all the surplus material to the level of the pond.

The slopes were protected on the northeast side of the embankment by 16 inches of stone paving, and on the southwest side, where there was less exposure, by 12 inches of stone paving. The top of the embankment and about 2 feet of the side slopes were seeded down with grass, and the conduit presents rather an ornamental appearance as it winds through the pond.

Water was sent to Chestnut Hill through the new conduit in July, 1886. It has been in periodical use since that date. I am informed by the engineer in charge of the works that inspection of the work since its completion has failed to find any evidence of either settlement or lateral movement.

A detailed force account was kept of the work, which is here appended:

CONSTRUCTION ACCOUNT OF FARM POND CONDUIT; WORK PREVIOUS TO DECEMBER 1, 1885.

WORK DONE.

Trench on Shore.—2,100 lineal feet of trench, 20 feet wide, 9.5 feet deep, contains 15,-106 cubic yards or 719 cubic yards per lineal feet; backfilled 1 foot over arch, then embankment made, averaging 1.5 cubic yards per foot; water in pond, 3.5 feet higher than bottom of trench; water handled by two pulsometers.

Cost to excavate per lineal foot	$3.20
" " brace per lineal foot	.40
" " pump per lineal foot	.45
" " backfill per lineal foot	.71
" " bank per lineal foot	.69
Cost, miscellaneous, per lineal foot	.28
	$5.73

Backfill cost 18 cents per yard; labor of bracing, 30 cents per foot of trench.

Trench in Pond.—1,551 lineal feet excavated to grade, 18 feet wide, contains 8,070 cubic yards; backfilling and embankment partially completed; water in pond, 6.0 feet higher than bottom of trench; water handled by two pulsometers and one Andrews pump.

Cost to excavate per lineal foot, $3.25; cost to brace, labor, 29 cents, lumber, 45 cents, total, 74 cents; cost to pump, 72 cents. The backfilling cost 19 cents per yard.

Pile Caps.—280 caps, sawed, notched and fitted. Cost to saw piles and fit bolsters and caps, $2.95; cost to saw away earth, 90 cents; cost of treenails, 16 cents; cost, miscellaneous, 26 cents; total, $4.27 per cap.

Timber Platform.—Cost of lumber, $14.90; cost to handle, $6.94; cost of fastenings, $1.19; cost, miscellaneous, $1.37; total, $24.40 per thousand feet B. M.

Concrete Masonry.—Cost for labor, $1.70; cost for cement, $1.66; cost for sand, 45 cents; cost for gravel, $1.20; cost for forms, 5 cents; cost, miscellaneous, 48 cents; total, $5.54 per cubic yard.

It took 1.32 barrels of cement to make one cubic yard of concrete; 2,495 cubic yards were laid, but only 2,453 cubic yards were paid for, as the balance was not protected from frost. Cost figured on 2,495 cubic yards; value figured on, 2,453 cubic yards.

Brick Masonry.—Cost of laying, $2.38; cost of tending (includes culling, unloading, etc), $2.07; cost of brick, $5.59; cost of sand, 42 cents; cost of cement, $1.55; cost of forms, 19 cents; cost, miscellaneous, 1.05; total, $13.25 per cubic yard; 1,615 cubic yards laid, 1,600 cubic yards paid for; 570 brick in 1 yard of work; 5 per cent. was added to this for waste. It took 1.23 barrels cement to lay 1 yard of work. Masons averaged 1,250 bricks per day.

Rip Rap.—It cost 71 cents per cubic yard to handle and place.

Trench on Shore.

Cost to Contractor.		Value to City.
Column No. 1	$346.00	
Column No. 2	11,107.45	
Twenty per cent. column No. 11.	593.35	
	$12,046.80	$8,610.00
Cost per lineal foot.		Contract price.
$5.73		$4.20

LABOR	SETTING UP MACHINERY			EXCAVATING TRENCH ON SHORE			EXCAVATING TRENCH IN POND			PILE CAPPING		
	DAYS WORK	RATE	AMOUNT	DAYS WORK	RATE	AMOUNT	DAYS WORK	RATE	AMOUNT	DAYS WORK	RATE	AMOUNT
FOREMAN				66	4 00	264 00	35	3 50	122 50	58	3 50	203 00
FOREMAN				159	2 50	397 50	150	2 50	375 00			
ENGINEMAN				123	2 50	307 50	146	2 50	465 00			
FIREMAN				147	1 75	257 25						
MACHINIST	75	3 00	225 00									
PUMPMAN				94	3 00	282 00						
PUMPMAN				56	1 75	98 00	286	1 75	500 50			
LABORER				2400	1 25	3000 00	400	1 65	660 00			
LABORER	79	1 50	118 50				460	1 50	690 00	50	1 50	75 00
LABORER				2200	1 50	3300 00	2500	1 25	3125 00	140	1 25	175 00
BRACER				366	1 75	640 50	255	1 75	446 25			
WATCHMAN												
WATERBOY												
MASONS												
CARPENTER	1	2 50	2 50	7	2 00	14 00				249	2 50	622 50
TIMEKEEPER												
HORSE AND CART				88	4 00	352 00						
HORSE AND CAR				10	3 15	31 50	12	3 15	37 80	2	3 15	6 30
SCRAPER				71	5 00	355 00						
MISCELLANEOUS												
TOTAL			$346 00			$9299 25			$6422 05			$1081 80
MATERIALS	VALUE											
BRICK	$8 40 PER M											
CEMENT	$3 20 PORT. 1 26 AMERICAN											
SAND	1 20 PER CU YD											
GRAVEL	1 20 PER CU YD (SEE COLUMNS)					•						
SPRUCE LUMBER	$15 00 / 14 00 M FT BM						49 M LEFT IN @ 14 00		686 00			
IRON	$.03 PER LB					15 00			5 00	OLD BOLTS USED COST IN LABOR		
RIPRAP												
TREENAILS	$.02											45 00
MISCELLANEOUS						26 00			30 00			
TOTAL						$41 00			$721 00			$45 00
PLANT												
CARSON MACHINE	$45 00 PER WK			10 WEEKS		450 00						
ENGINES	$2 00 " DAY			103 DAYS		206 00	125 DAYS		250 00			
BOILER	$1 00 " "			129 DAYS		129 00	125 DAYS		125 00			
PUMPS	$.80 PILES .25 FEED			199 DAYS		159 20	223 DAYS		178 40			
PUMP	$2 00						67 DAYS		134 00			
DERRICKS	$1 00 PER DAY			72 DAYS		72 00	125 DAYS		125 00			
CARS						6 00			7 00			1 00
TOOLS LOSS, WEAR AND INTEREST						65 00			50 00			10 00
FORMS & CENTRES												
COAL	6 00 PER TON			80 TONS		480 00	52 TONS		312 00			
SHEETING	$14 00 M FT BM			LOSS ON		200 00	$686 00 SEE ABOVE					
OFFICE EXPENSES												
TOTAL						$1767 20			$1181 40			$11 00
GRAND TOTAL						11107 45			8324 45			1137 80

LABOR	TIMBER PLATFORM			CONCRETE			BRICK WORK			BACKFILLING AND PULLING SHEETING			LAYING RIPRAP			GRAVEL AND SAND			MISCELLANEOUS		
	DAYS WORK	RATE	AMOUNT	DAYS WORK	RATE	AMOUNT	DAYS WORK	RATE	AMOUNT	DAYS WORK	RATE	AMOUNT	DAYS WORK	RATE	AMOUNT	DAYS WORK	RATE	AMOUNT	DAYS WORK	RATE	AMOUNT
FOREMAN	2	4 00	8 00	62	3 00	186 00	39	5 00	195 00							9	4 00	36 00	2	4 00	8 00
FOREMAN	36	3 00	108 00	85	2 50	212 50							30	2 50	75 00	204	2 50	510 00	7	2 25	15 75
ENGINEMAN																					
FIREMAN																					
MACHINIST																			2	3 00	6 00
PUMPMAN																					
PUMPMAN																					
LABORER				172	2 25	387 00	25	1 25	31 25							751	1 50	1126 50			
LABORER	37	1 25	46 25	1855	1 65	3060 75	1752	1 50	2628 00				109	1 50	163 50				230	1 50	345 00
LABORER	256	1 50	384 00				295	1 25	368 75				400	1 25	500 00	1811	1 25	2263 75	184	1 25	230 00
BRACER																					
WATCHMAN																			307	1 75	537 25
WATERBOY																			301	1 20	361 20
MASONS							735	4 90	3601 50												
CARPENTER	44	2 50	110 00				4	2 50	10 00										59	2 00	113 00
TIMEKEEPER																					670 00
HORSE AND CART				6	3 50	21 00							18	4 00	72 00	94	3 50	329 00			
HORSE AND CAR	5	3 15	15 75	110	3 15	346 50	90	3 15	283 50				14	3 15	44 10				5	3 15	15 75
SCRAPER																					
MISCELLANEOUS				22	1 25	27 50	19	1 25	23 75												
TOTAL			$672 00			$4241 25			$7141 75						$854 60			$4265 25			$2306 95
MATERIALS																					
BRICK							960000		9024 00												
CEMENT				3300 BBLS		4158 00	315 @ 3 20 / 16815 LBS		1008 00 / 2118 06										16 BBL SPL. CO / 60 " "		51 20 / 75 60
SAND				945 CU YDS		1134 00	571 CU YDS		685 20												
GRAVEL				2495 CU YDS		2994 00															
SPRUCE LUMBER	90.4 M @ 15 00		1356 00																2 M WASTED		30 00
IRON			115 00			75 00															250 00
RIPRAP													260 CY @ 1 00 / 435 " @ 1 20		260 00 / 522 00						
TREENAILS																					
MISCELLANEOUS	6.1 M FOR CRIBBING @ 14 00		85 40	CEMENT SAND AND GRAVEL WASTED		75 00							CARS		8 00						
TOTAL			$1556 40			$8436 00			$12835 26						$790 00						$406 80
PLANT																					
CARSON MACHINE																					
ENGINES																					
BOILER				20 DAYS		20 00	15 DAYS		15 00												
PUMPS				101 DAYS		25 25	101 DAYS		25 25												
PUMP																					
DERRICKS																					
CARS			3 00			66 00			54 00												3 00
TOOLS LOSS, WEAR AND INTEREST			10 00			25 00			25 00												
FORMS & CENTRES						125 00			304 00												
COAL				12 TONS		72 00	12 TONS		72 00												
SHEETING																					
OFFICE EXPENSES				CEMENT SHED		100 00	AND OFFICE		57 00												250 00
TOTAL			$13 00			$433 25			$552 25												$253 00
GRAND TOTAL			2241 40			13110 50			20529 26						1644 60						2966 75

BACKFILL & ON SHORE COST $2943 00 IT IS INCLUDED IN THE TRENCH ACCOUNT

BACKFILL & IN POND COST $1036 00 IT IS INCLUDED IN TRENCH ACCOUNT

200 CU YDS BOUGHT THE REST WAS SCREENED FROM THE CITY LAND OR LAND ADJACENT AND IS INCLUDED IN THE LABOR COL.

755 CU YDS LAID FOUND ON THE GROUND
440 " " " BY CONTRACTOR
500 " OF THE ABOVE WERE STRIPPED OFF THE OLD SLOPE, COST IN THE EXCAVATION COLUMN ABT $150
260 CU YDS BOUGHT @ 1.00
435 " " SCREENED @ 1.20

$4265 25 SPENT IN SCREENING SAND, GRAVEL AND RIPRAP
1435 00 " BUYING THE REST OF THE MATERIAL REQUIRED
$5700 25 THIS AMOUNT REPRESENTS 2405 CU YDS CONCRETE GRAVEL LAID, 200 CU YDS DELIVERED; 1516 CU YDS OF SAND USED AND 20 CU YDS DELIVERED, 440 CU YDS OF RIPRAP LAID 180 CU YDS DELIVERED.
THIS GIVES AN AVERAGE OF $2 20 PER CU YD

CONSTRUCTION ACCOUNT FARM POND CONDUIT.

Applies only to work done up to Dec. 1, 1885.

	Trench in Pond.		
Column No. 3	$8,324.45		
Fourten per cent., column No. 11.	415.35		
	$8,739.80	$3,755.51	
	Rip Rap.		
Column No. 9	$1,644.60	80.00	rip rap delivered.
Two per cent., column No. 11	59.36		
	$1,703.96	$2,451.60	
	Concrete.		
Column No. 6	$13,110.50	$9,812.00	concrete laid.
Twenty-three per cent., column No. 11	682.35	200.00	gravel delivered.
	$13,792.85	$10,012.00	
Cost per cubic yard. $5.54		Contract price. $4.00	
	Brick Masonry.		
Column No. 7	$20,529.26	$23,033.73	regular work
Thirty-five per cent., column No. 11	1,038.36	605.35	Port. cement.
		154.17	extra bills.
	$21,567.62	$23,793.25	
Cost per cubic yard. $13.25		Contract price. $14.50	
	Pile Caps.		
Column No. 4	$1,137.80		
Two per cent., column No. 11	59.33		
	$1,197.13	$840.00	
Cost of one cap. $4.27		Contract price. $3.00.	
	Spruce Lumber.		
Column No. 5	$2,241.40	$2,736.00	timber platform.
Four per cent., column No. 11	118.66	168.00	boards for drains.
	$2,360.06	$2,904.00	
Cost per M. Ft. B. M. $24.40.		Contract price. $30.00	

SKILL AND ART IN THE HEATHEN ERA.

BY J. T. FANNING, READ BEFORE THE MINNEAPOLIS SOCIETY OF CIVIL ENGINEERS.

Professor Tyndall, referring recently to the rapid development of science in the present age, and to the increasing public interest in its results, spoke also of science as being now the supreme interest of civilization. We observe its influence working in public school and collegiate institution, and already it threatens to overshadow the long-established classical régime in the universities.

In the department of building, science has given rapid transferrence of thought and commands from office to workshop and quarry, rapid and easy transportations of materials and rapid accumulations of mechanics and supplies wherever great structures are to be erected. If canals, aqueducts, bridges or halls of legislation are now to be constructed, science has shown how to increase the results of the manual labor in them a hundred fold, and it has so multiplied constructive possibilities that we contrast with pride our splendid modern facilities with those of the workmen of old, who toilfully dug with rude utensils such ditches as our steam shovels excavate at surprising rate, or who slowly rolled up long inclines

such blocks of stone as our hoisting engines quickly whisk up three, five or seven stories height.

While the results of science are of general interest and accrue to the general benefit, there are none who more fully appreciate the scientific development of our time, with its increase of opportunity and power, than engineers and architects, its devotees, for they, chiefly, design and direct the construction of the notable works of the age, which present the highest applications of scientific skill, and whether these works be revetment, aqueduct, truss or temple, their acknowledged successes are measured, more than all else, by the influence of the skill and art that pervades them.

Modern buildings are in harmony with the advanced stage of modern civilization, and so public works in each generation, and we might say in each city and village, are and have been constructive expressions of the civilization of their time and locality. They are a portion of Nature's historical record of the necessities, desires and mental status of the people who projected them, as well as of the acquirements of the architectural engineers who designed them.

While the public works of the different eras may not claim our attention as models for modern reproduction, they offer a line of study of most intense interest in the unimpeachable history which they present of the advancing or retrograding stages in evolutions of national thoughts along the varied ethnological successions, and teach us of the origin of the inherited skill and artistic development which our era is not too modest to claim. In a comprehensive view along the structural eras of the past, the lapse of time covered by structural history gives us power to note the characteristic features of the early works, and through them to individualize the ancient workers, and to study their distinctive traits as shepherds, invaders, migrators, traders, and as artizans or idolators.

Thus through the aid of such *bas-reliefs*, intensified by time, we analyze the peculiarities of the Egyptians, Hebrews, or Greeks, as nations, as through familiarity we are enabled to perceive in clear relief the personal characteristics of our individual neighbors and intimate friends.

Individuality in nations has a broad significance, and its study in the ancients will not only add interest to, but help us to understand more thoroughly, our own distinctive characteristics, our precious inheritance of mental power, with mechanical and technical skill, scientific acquirement and artistic preception. And there is an ever-recurring interest in comparisons of the skill, talent and genius of the moderns, with the like faculties of the earliest people of whom we have any history or tradition, who fulfilled their political destiny several thousand years ago.

In prosecuting our studies of the ancient people and their works, it is convenient to arrange the gathered facts first in inverse chronological order, as in a lengthy panorama, and glance from the modern standpoint backward, till the view is lost in the distant perspective, and then with the advantage of more familiarity to reclassify in true order of sequence. Ancient skill is more ancient in origin than art, and has

in much less degree attracted the attention of historical writers, and for our knowledge of it we are dependent more on the remains of ancient works than upon written history. Skill, as well as art, has had its culminating periods of progress and then its periods of neglect, and these have in general been introductory to and contemporaneous with advancements and declines of art. Its periods of great progress may be broadly classified, as is usual with art, into *ancient*, *mediæval* and *modern*. Ancient skill and art had their full measure of glory, and came to their decline under heathen patronage before mediæval skill and art felt the inspiration of Christian influence.

The student of ancient history who would commence his studies with the character of the people and works of skill at the early dawn of civilization, and trace them in order of sequence to the middle age, is surprised at the outset to discover that there are few traces of reliable ancient history in existence antedating the classic age; other than that wrought by bone and sinew into enduring canals and tombs and temples. Were it not that certain royal constructions of the ancients endure 'till to-day the records of ancient peoples, once powerful in influence and in deeds, would long ago have passed into tradition and myth. Starting in ancient historical research from the classic age and classic lands, the student is led backward step by step towards the east, and finds himself guided by footprints of a host of noble seekers after knowledge,—Pythagoras, Solon, Strabo, Tacitus, Archimedes, and many others who journeyed in the early days down into Egypt, a birthplace of skill, science and art, to drink there their fill from an ancient fountain of knowledge.

In Egypt the philosophers early learned to distinguish the constellations, to foretell eclipses and to reckon time: to divide and compute geometrical areas and to survey the lands after the inundations. There the builders early learned to quarry and to hew stones, and there the agriculturists early learned to irrigate the lands which the rains of heaven rarely fell upon. It is natural that in a rainless country beneath a tropical sun, the earliest development of skill should be in the practice of irrigation, and tradition relates that hydraulic works were commenced almost immediately upon the arrival of the Hamitic colony of Mizraim in Egypt. Through the agricultural necessities and opportunities on the plain this people became practical hydraulicians, and developed the instincts that led to the construction of those vast irrigation works, which, together with lesser works of recent date, are this day watering Egypt, Chaldea and India. Reference to a few only of their great works will be necessary to show to what skill they attained, and these references may be chiefly to hydraulic works because they are less familiarly known to students of art literature. From the very border of traditionary history comes the story that Menes, whom the priests named to Herodotus as the head of the first great dynasty of Egypt, diverted the mighty Nile from its course and established his palace and the city of Memphis over its former bed, where they became the centre of rule of the great Memphian kingdom before the foundations of the first pyramids were laid. At a later period when Sesostris, a powerful monarch, returned from his successful Asiatic campaign with a horde of captives and with spoils from every kingdom

between the Persian Gulf and the Euxine, he began a systematic irrigation of the valley of Egypt, and dug numerous water-courses, intersecting the whole plain. To enhance the usefulness of these and additional canals Mœris is said to have planned and completed, four thousand years ago, the immense reservoir that now bears his name, and to have dug a canal from the upper river to the newly formed lake to retain the Nile floods for the irrigation of the lower valley of Egypt. It is claimed to have had originally a circumference of four hundred and fifty miles. Rising out of the basin now exists the great pyramidal tomb of Mœris. Lake Mareotis also, and other great reservoirs, were improved, excavated or brought into use for storage of the Nile floods, so that each season of irrigation might be prolonged and the agricultural products of the country multiplied.

Pharaoh Necho, six hundred years before our Chistian era, constructed a maritime isthmus canal, extending from the Nile near Heliopolis to the Bitter Lake Basin, through which the recently excavated isthmus canal passes, and thence to the Gulf of Suez at the head of the Red Sea. The breadth of this ancient ship canal is given as one hundred feet, and depth as forty feet, and its length exceeded that of the modern isthmus canal. Strabo states that ships of the largest size could navigate it. This canal was in use five hundred years, until after the time of the Ptolemies, and then neglected until it was partially filled by drifting sands. Twelve hundred years after its first construction it was re-opened by the Caliph Omar, and continued in use one hundred and twenty years, until the destruction of Alexandria. Recently it was again opened in part, to lead potable waters to laborers on the modern Suez canal. At Cairo there is an aqueduct three thousand years old, and Savery, a French explorer, discovered great reservoirs hewn in the rocks upon the hills in different parts of Egypt, from which water once flowed to irrigate the land. While these remarkable hydraulic works in Egypt were being developed, the kings, in succession, were building their mighty pyramidal monuments and setting their lofty obelisks, excavating their wonderful rock temples and constructing massive palaces and places of worship which have served for a basis of later classic skill and art. The beautiful temple of Tentyra is now beheld by the traveler who ascends the Nile as one of the legacies of ancient skill, and has ever proved a monument of wonder and delight. A traveler of renown, standing beneath its portico, was so enraptured as to exclaim that he really was in the sanctum of arts and sciences.

The Serapeum at Memphis was a magnificent group of temples, approached from the city through an avenue of Sphinxes. The subterranean tombs of these temples are remarkable in extent, and contained enormous sarcophigi of granite, sometimes twelve feet high and fifteen feet long, and weighing more than one hundred tons each. The colossal statues of Rameses II. were carved of syenitic granite, above seventy feet in height, and were set up in ancient Memphis. One of these exists as the fallen colossus. The Egyptian Labyrinth, erected near Lake Mœris, about 1800 B. C., contained twelve palaces under one roof, and is said to have had a peristyle court and three thousand chambers, and many vaulted passages. It was constructed of polished stone with pil-

lars and columns of granite and porphyry. It is said that the opening and closing of its doors echoed like the reverberations of thunder. Herodotus and Strabo visited this palace and found it difficult to explore its labyrinthian halls without a guide.

In the absence of trustworthy written records of the ancient peoples, the history of their migrations is obscure, and the conjectures respecting them are conflicting among the best authorities, nevertheless, there is very convincing mechanical evidence in the ruins of vast hydraulic works still observable far to the eastward that the early people of Mizraim prospered and multiplied in a degree unapproached by other descendants of Noah, and that in consequence of their prolific growth from their Egyptian base, they, in the far distant past, advanced like an inundation, eastward along the tropic of Cancer, across Arabia and Chaldea, past the Persian Gulf and down into the peninsulas, possessing the coast along the Indian Ocean to the northeastern shore of India. If search is made for their hydraulic skill in Chaldea, there may be observed in the extensive plain where the waters of the Euphrates and Tigris meet, traces of great reservoirs and canals. There the floods were stored for irrigation of the plain, as the earlier Cushites had stored the waters of the Nile.

When Babylon of old became a capital on the great river, the Chaldeans taught her Shemitic rulers to protect the city from inundations by diverting the surplus water from its natural channel into a new course and into storage basins. Our Hebrew record relates that Cyrus, when afterward investing Babylon, deepened this same diversion channel and dried the bed of the Euphrates, and thus admitted his army within the walls of the doomed city while Belshazzar and his thousand princes were stupified with feasting and revelry.

Search for their hydraulic skill in India also discovers immense bunds, or storage reservoirs, constructed before the period of written history, and they may be counted more than one hundred thousand in number, many of them built most substantially of stone. Some of these masonry dams still retain ruins of their ancient temples that crowned them. In Ceylon may be cited a great dam extending across a valley, which is said to be fifteen miles in length, and is faced with huge blocks of stone well cemented together, and originally confined a lake of great extent. In India we find also the great monuments, the obelisks and the rock temples, such as are more familiarly known to European travelers in Egypt, and the great subterranean temples at Elephanta, Ellora, Salsette and Canara have been explored and the similarity of their sculptured walls and pillars to those of Egypt discovered. It has been estimated that it would require the labor of forty thousand men forty years to excavate and carve the temple at Salsette by the supposed methods originally employed.

It may be asked why these far-off works are attributed to colonists of Egyptian origin, since they are of a pre-historic age. Shrewd ethnologists have observed that the early independent colonies springing, as the Hebrew record states, respectively from Shem, Ham and Japhet, developed each peculiarly distinctive characteristics, practical, artistical and intellectual, as well as moral. The Hamites, whose works we have been

referring to, and whom the ethnologists term Turanians, have especial instincts and talents for irrigation and building, and wherever they wandered they fixed indelibly their mark of reservoir and canal, and tunnel, and huge structures of enduring masonry. The Semites and the Aryans and Celts, descendants of Shem and Japhet, never did, and possibly because of political and religious influences, never could build such vast and enduring structures. If we recognize these peculiarities of the original colonies as separated in early post-diluvian times, it will add intensely to the interest of the study of their habits, while still remaining and diverging as distinct races, and we shall watch with interest the results as effecting skill and art, where they are again brought into close intercourse many centuries later in the all absorbing Roman Empire.

It was these Turanians of the early Memphian kingdom, who, under the influence of idolatrous worship and absolute monarchical rule, first became intuitive and mighty builders, building, as it were, for eternity the most mighty monuments of any age, that still remain, and so old that we cannot with certainty fix their dates within a thousand years. The sublime structures themselves, with their hieroglyphic inscriptions, are the only records remaining of the ancient people who first invented science and art.

These mechanical instincts, first developed in the Memphian kingdom, again assert themselves in the wonderful temples and palaces of the Thebian kingdom in Egypt. There the arts of quarrying, stone cutting and symbolic sculpture, and the skill to transport and handle heavy weights, were brought to great perfection, and there we may find long and deep stone lintels weighing one and two hundred tons each, placed high upon pillars, or as roofings of apartments, and there we may find whole structures built of massive blocks of stone, such as modern masons' riggings are by no means adapted to handle. Those ancient mechanics could square stone with the most scrupulous accuracy, and polish their faces to surfaces like glass, and set them with the utmost precision, and those same old workmen could also excavate in solid ledge such palaces or temples as their kings or priests required, leaving portal and pillar and partition in place, enlivened with emblematic sculptures; or they could, when their religion demanded, chisel a hill of rock into a gigantic sphinx with a temple between its paws, or into a massive tomb, moulding the everlasting hill into everlasting art.

Searching again for the colonial influence of this building instinct, we find that the early Phœnicians displayed mechanical skill not unworthy an offspring of Egypt.

Some eminent philologists, noting that the language of the Phœnicians has been within the historic period more closely allied to the Assyrian than the Egyptian tongue, have claimed them to be of Semitic origin. The evidences of their mechanical instincts, and of their moral instincts, very strongly indicates them, or otherwise an influential infusion among them, to be of Turanian origin. Moses calls them Canaanites. Good authorities, on the basis of their own traditions, claim them to have been a colony from the vicinity of the Persian Gulf, a land undoubtedly held by the Hamites at an early period. Whatever their origin, the Egyptian

mechanical influence asserts itself strongly in their public works, the ruins of which still indicate massiveness.

Strabo says that the walls of Tyre in Phœnicia were one hundred and fifty feet in height, and were built of massive blocks of stone, and that the remains of its aqueduct are of the most solid construction.

Also in Carthage, a daughter of Tyre, founded nearly three thousand years ago, traces of sewers remain, and great reservoirs are now to be seen near the western walls. Cressy says the ruins of the Carthaginian aqueduct may be traced a distance of fifty miles, including a thousand arches of beautiful masonry which are upward of one hundred feet in height.

In Syracuse, which we remember as the birthplace of Archimedes, that had 1,800,000 inhabitants when besieged by Marcellus (B. C. 212), there is now to be seen a great reservoir cut out of solid rock. There a tunneled conduit extends from Syracuse under the sea to the island of Ortygia, which we may justly regard as a remarkable example of ancient subaqueous engineering.

That the Hamitic people still excelled in skill in Solomon's time is evident by the biblical record that Solomon sent to Egypt "a thousand and four hundred chariots" at one time, and when Solomon had decided to build a great temple to the living God, he sent for Phœnician workmen, and Hiram of Tyre was his chief artificer, who came to beautify and adorn the temple, which, when completed, "every part thereof fitted with that exact nicety, that it had more the resemblance of the handiworkmanship of the Supreme Architect of the Universe, than of human hands."

We cannot attempt here to catalogue, even, the great works that mark the migrations of those Hamitic builders to the east, and to the west along both shores of the Mediterranean. But in a review of remarkably great works of the ante-classic age, it is proper to take note of the marks of skillful builders, who in the distant past possessed portions of Mexico and Peru.

Ewbank, speaking of ruins of ancient hydraulic works in Mexico, Peru and Chili, says, "some of them rival in magnitude those of Egypt and India, and the roads equaled in utility the oldest works of Greece and Rome." The base of the great pyramid of Cholula, which is by some Mexican explorers attributed to the Toltecs, and who are by some ethnologists classed as Turanians, measures 1,440 feet, a little more than one quarter of a mile on each side, and covers nearly four times the area of the largest Egyptian pyramid. The great pyramid of Palenque was carried to a height of 60 feet and then surmounted with a temple.

Humboldt says that few nations moved such great masses of building stone as those unknown people of Central America.

In the rainless lowlands of Peru hydraulic skill was as much a necessity as in the plains of Egypt and Chaldea. Says Humboldt, "In the maritime parts of Peru, I have seen the remains of walls along which water was conducted for a space of from 5,000 to 6,000 metres, from the foot of the Cordilleras to the coast." Examples are mentioned of water being conveyed sixty miles to irrigate a small territory, and Acosta describes an aqueduct of 120 leagues, or 360 miles in length, which at its fountain

seemed to be a river, also another of 150 leagues in length from north to south, which traverses a whole province, and extends from the mountains to the plains.

Acosta, when examining the ancient buildings in Peru, was at a loss to comprehend how they could have been erected, so large, well cut, and so closely jointed were the stones.

In the pre-historic times there was another colony whose origin is still in dispute, though probably Turanian, that planted itself on the north shore of the Mediterranean, and excavated tombs, and built strongholds of Cyclopian masonry about the Archipelago. We call them Pelasgians. They built dams and canals of surprising magnitude and of skillful construction, and infused into their conquerors an influence, without which the temple of Diana at Ephesus would have been impossible. We see traces of their works at Athens, at Eleusis and Isene, and at Samos, where there is a conduit tunnel originally counted one of the seven wonders of the world.

Also a colony whose origin is uncertain, but claimed to be Pelasgic, planted itself on the west coast of the Italian peninsula, and at the dawn of history were excavating temples in the rocks similar to the Egyptian models, and adorning their entrances with massive façades of columns and lintels and majestic sculptures. We call them Etrurians.

Their advance in civilization expressed itself in innumerable works of masonry of massive character, and in works of art. They drained and sewered their towns, reclaimed marshes and embanked lowlands. So skillful were they in engineering works of magnitude and public benefit, and so skillful in surface decoration of their houses and wares, that the Latins who afterwards absorbed them became their willing disciples in skillful building and in art.

It seems that in process of time those Turanian colonists that separated from the Egyptian homestead, disappeared, or were absorbed by conquests, leaving only their constructive impressions in the lands they possessed for a time; but they made their marks as though for eternal mementos of their presence.

The home colony survived, with occasional disaster, till within the historic period, and as the successive Egyptian dynasties flourished, then were wrought in Egypt such great national works and structures, that beside them, so far as magnitude and massiveness are concerned, our modern works seem feeble in comparison, and so far as mechanical finish of decorations is concerned, Viardot informs us that their statues and bas reliefs in granite, porphyry, diorite and basalt have often a fine polish and exquisite delicacy suitable to cameos and precious stones.

Then the *mechanical* treatment of stone reached with the Turanians a perfection not since surpassed, but the highest esthetic and scientific treatment of stone was waiting for other more intellectual and refining influences.

At the dawning of history we find in the upper peninsula of Greece and in adjacent portions of Asia Minor groups of inhabitants of undoubted Japhetic origin. They in time absorbed the Pelasgic builders and began to build temples worthy of dedication to the gods and goddesses of their religious system, to gather towns about their temples, to

establish republican systems of government, to build gymnasiums for physical development and to build forums for public discussions and mental development. They became at the dawning of the classic age the most prosperous and enlightened branch of the so-called Aryan race. As a result of their thrift Argos, Mycenæ, Athens, Sparta, Thebes and Corinth grew to wealth, power and renown: their merchants were princes and their scholars were giants in intellectual power. Intellectual strength was as marked a characteristic of their race as mechanical skill of the Turanians. Out of their mental resources came in due succession the poems of Homer, the laws of Lycurgus, the architecture of Ictimus, the sculptures of Phidias and the bronzes of Polycletus, each unsurpassed to this day in intellectual excellence.

The cities of Greece welcomed the skilled artisans of Phœnicia, and the expert workmen of Etrurua encouraged their Pelasgic masons, and became themselves most excellent builders. They superadded to mechanical excellence an artistic influence that gave to the art of building the intellectual refinement of form and proportion that found expression in such structures as the Doric temples of Juno at Argos, and of Jupiter Olympus; the Ionic temple of Apollo Panonius and the theatre of Laodicea; the Corinthian monument of Lysicrates and Arch of Adrian, and in the Parthenon at Athens. By their hands the esthetic treatment of stone, in temple, in monument, and in mythological sculpture, reached the utmost perfection yet attained.

The scientific treatment of stone was then advancing toward excellence among the dome builders of northern Italy, and afterwards reached in the vaulted arches of the southern cities a high degree of perfection, culminating in the domes of St. Peters at Rome and St. Sophia at Byzantium.

At the time of the death of the Grecian Emperor, Alexander the Great (323 B. C.), the Roman Republic, embracing Latins and Etrurians, was already established and thriving, and in a brief time it gathered in by conquest the *Aryan* colonies of Greece, the *Turanian* colonies of Carthage and Egypt, and *Semitic* colonies of Syria and Assyria, and to the northward the *Celtic* colonies of Gaul and Briton, and boasted the rule of three thousand five hundred cities, so that a half century before our era she

> "Reignèd absolute, the mistress of the world;
> The mighty vision that the prophets saw
> And trembled."

Rome had then at command all the elements out of which develop with spontaneous growth durable and magnificent building, for they possessed the *mechanical* skill of the Turanians, the *scientific* skill of the Celts, the *artistic* skill of the Aryans and the *financial* skill of the Semites, and the wealth of all civilized cities paid her tribute.

It was during the three centuries of the expansion of the Roman Empire that her most beautiful temples and theatres and her greatest aqueducts were built and the fountains and public baths of her capital assumed their most magnificent splendor, and her Roman architecture rivaled in elaboration that of Corinth and Athens. Tarquin the elder, who was of Etrurian birth and Pelasgic descent, projected the cloacæ for the purifi

cation and drainage of Rome, and his grandson Tarquinius Superbus completed the *cloacæ maxima* famous for its size and the stability of its arch masonry, which, though 2300 years in use has ever been a wonder to visitors because of its magnitude and excellent workmanship.

Frontinius, an officer of renown, appointed by Nero to the charge of the aqueducts of Rome, gives the total length of the nine great aqueducts as 277 miles, 31 miles of which were on arcades. On the plains near Rome may be seen most of these splendid masonry arcades, partly in ruins, nevertheless monuments of the mechanical skill and artistic treatment of two thousand years ago. Within the city of Rome the masonry of some of the aqueducts was embellished with elaborate architectural ornament, as for instance Aqua Virginie, which has a façade of the complete Corinthian order with columns and entablature in full relief. At some of the main thoroughfares which the aqueducts span, the arcades equal in grandeur and nobleness of design triumphal arches, and bear inscriptions; and certain *castella* exhibit choice examples of classic architecture and sculpture.

If we had time now to examine the most important of the colonial work of the Romans previous to the decline of the empire. we should find it to include some of their boldest works, and we should find their most skillful works to be aqueducts and amphitheatres.

For instance, one of the great aqueduct bridges of the Pisan aqueduct, with its thousand arches, is still famous, and the *Pont du Gard*, projected by Agrippa at Nismes is famous, and the aqueduct supplying Lyons has one arcade of three stories of arches, another of five stories of arches, and still another of eight stories of arches, with total height of nearly three hundred feet; and for instance also the great amphitheatres at Capua, at Nismes and at Verona, as remarkable in magnitude and decoration for colonial works as the great Colosseum at Rome for a splendid metropolitan structures.

These brief references to the splendid and durable workmanship of the ancients must not be considered exhaustive of the range of their works even.

We might also trace the growth in their mechanical skill in harbor works, in the moles and piers and fortified entrances of the Phœnician, Greek and Roman ports, that grew out of their commercial necessities, also in their great walls, towers, and massive gates that grew out of their military necessities, or in their bridges, which in the hands of the early Romans displayed such thorough knowledge of the regimes of rivers, and of foundations. and of counter-arching that they became practical models for the more theoretical engineering of France and Britain many centuries later.

The gathering in of the best talent of the subject races to the powerful Roman capital and Roman cities bore good fruits in the production of very many well considered buildings of most thorough workmanship and elaborate details and admirable models of usefulness. Their masonry, proportions and decorations have exerted a strong influence in subsequent buildings in the classic revivals.

The dominant race had not, however, the fine feeling that enabled them to appreciate and generally embody in their works the chaste beauty of

the Ionic builders, so that while mechanical building advanced in usefulness, art, in its highest application to domestic and municipal structures, began to recede, even while the glory of the Roman Empire was in ascendency.

In time the glory of the Roman Empire culminated, and the period of ancient skill and art rapidly declined. About three and one-half centuries after the beginning of the Christian era (364 A. D.) the dismemberment of the Roman Empire began. The exultation of conquest was no longer an incentive to great public undertakings. On the contrary there was a decrease of national energy, and a decrease of national revenues. The desire for durable structures and artistic embellishments gradually weakened, and there was no longer a pressing demand for skilled workmen and skillful artists.

From this period, fifteen hundred years ago, the historical study of ancient mechanical skill and more especially of ancient fine art leads into a quiet gloom, for the arts then began a slumber of five centuries duration in nearly all Europe, through the long night of the "dark ages."

The examples of wondrous skill among the ancient mechanics, though now much scored by the storms of twenty to thirty centuries, are still so numerous that this brief sketch but suggests a research among them.

Omitting now a consideration of mediæval skill and art, we pass from the assembled Turanians, Aryans, Semites and Celts under Roman conquest to a present period when, after twenty centuries interval, imperial liberty and prosperity are gathering anew, on American soil, the stock and traits of Semite, Aryan and Celts, with their financial, artistic and scientific instincts, and out of which, under a fair financial stimulus, ought to grow public structures of wondrous skill and beauty, but the spirit of the Turanian, the mighty builder, has not here an influential representative.

We are proud of the mastery of the forces of nature, our mechanical inventions, our splendid trusses, and our technical refinements of structures have not been surpassed in former eras. We are proud of an industrial progress that gives us almost unlimited constructive possibilities, but yet there remains to be developed an admiration and an introduction of enduring qualities in our structures.

If there is aught that is admirable in the public will of our generation that should awaken a spirit of reverence in later generations, then the standard of the public structures should respond to a natural demand, and out of the high scientific attainments, the constructive genius and the artistic refinement of which we boast, should be evolved structures that will be admired at least a century hence with admiration equal to that we give to the unquestioned skill and art of the heathen of ty centuries ago.

THICKNESS OF WATER PIPE.

By S. Bent Russell, Member Engineers' Club of St. Louis.

[Read April 18, 1888.]

To properly approach the subject let us rapidly review former conclusions as to the proper thickness of water pipe. Plates I., II. and III. give a graphical comparison of the formulas usually quoted. Plate I. shows the thickness given by the several formulas for 12-inch pipe for different pressures; Plate II. the same for 36-inch pipe by a few formulas, while Plate III. shows how the thickness varies with the diameter in the several formulas, the pressure being taken at 75 pounds per square inch.

We see at a glance that one has considerable latitude in choosing the proper thickness from these formulas.

In 1882 a paper by Mr. Baermann* gave an elaborate analysis of the formulas compiled by Mr. Fanning. Mr. Baermann gives also a valuable table of the minimum thickness which may be used for pipes of different size; said table being based on the thickness used in gas pipes.

Mr. Baermann proposes that the thickness of pipes be directly proportional to the diameter, except in the smaller sizes, which he says may be of the minimum thickness. He thus argues that the older formulas give pipes too thick in the smaller sizes and too thin in the larger sizes. His paper concludes with the following remarks: "Finally one of the main facts derived from the comparison is, that the values of t obtained from the formulas give pipes of *varying strength* when calculated for a *given head*, and that the least thickness consistent with proper casting and handling is ample in pipes of small diameters for *all ordinary heads*."

In 1885 a paper by Mr. Howland† gave the thickness of pipes of different sizes used in various cities and towns of America, and showed the great variation in thickness used under conditions apparently similar. Mr. Howland gives also a table of minimum thickness almost identical with Mr. Baermann's, and says thereof: "The minimum thickness of pipe which I give are strong enough to withstand ordinary strains of manufacture, transportation and laying." The line on Plate III. marked Howland's Min., gives the values taken from the table referred to.

Later in 1885 a paper by Mr. Noyes‡ gave graphical diagrams of thickness of pipes used in different towns and by the many formulas. Mr. Noyes remarks upon the wide variations in thickness used for similar conditions. He also lays stress on the importance of the problem in the way of economy.

In discussing this paper Mr. Howland said: "I think the tendency among the majority of engineers in this country has been to use too heavy pipe." And again: "I think the tendency has been to put altogether too much money in insurance by using too heavy pipes."

So much for history. Let us consider the

IMPORTANCE OF ECONOMY IN PIPE THICKNESS.

The water pipe now under ground in St. Louis would be worth, if new,

* Transactions Engrs. Club of Philadelphia.

† Trans. Am. W. W. Ass.

‡ Trans. N. E. W. W. Ass.

at present prices, nearly two millions of dollars. Had the pipe been made ten per cent. lighter $200,000 would have been saved in outlay, and the interest on this sum at 4 per cent. would amount to $8,000 per year. Say that by thus lightening our pipe we increase the number of leaks by 100 per annum, and that repairing a burst pipe costs $50 on the average, or $5,000 additional expense for maintenance. We have in this city an average of 125 leaks per year, or a leak to 2½ miles of pipe. Probably four-fifths of these, however, are in the joints.

We would then save by the reduction of weight about $3,000 a year. The question remains open, would the number of leaks have been increased by more or less than one hundred. We must not forget that a leak is undesirable more on account of the annoyance and danger to life and property than on occount of cost of repairing. Under some conditions also, much wàter may be lost by leaks remaining long undiscovered. We cannot abolish leaks altogether, however, and the problem might be put as the number of leaks per mile consistent with economy, or Capital vs. Leaks.

The cost of pipe need not be considered only as capital, for in the majority of American cities the pipe system must be extended at shorter or longer intervals to keep pace with the increase and spread of population, so that the cost of pipe used in extension may be charged up to annual expenses. St. Louis will hardly need less than $40,000 worth of pipe per year to keep up with her present rate of growth. If the pipes could be made 10 per cent. lighter, this outlay would be diminished by the sum of $4,000 per year.

Under some conditions the question of life of the pipe would come in with that of leaks, but I think it may be neglected here when the pipes are coated in the usual manner.

In some localities the question of thickness is of more importance than it is in this city; for example, in our Western towns the cost of transportation to which rivals that of manufacture of pipe. In many works, too, the cost of the pipe system is more than half the cost of the whole works, and in many a small town the question of water-works or no water works depends on the cost of the necessary pipe system.

Let us state in a few words

THE PROBLEM

which we are to consider:

What thickness of cast-iron water pipe will give the maximum *economy* for the different sizes and under the different conditions of water-works service? The word economy is here used in its largest sense.

The above problem may be separated into two. 1. What factor of safety will give the maximum economy in thickness of water pipe under the conditions of water-works service.

2. What thickness for pipes of different size and under different conditions of service will give the same factor of safety? or, to state the second more definitely, What function of the diameter should the thickness be and what function should it be of the known conditions of service to obtain a given factor of safety?

What data are necessary to solve the latter problem? Many formulas

appear to require only the pressure or static head and the diameter of the pipe ; some do not require the pressure to be known and others have a factor for the ultimate strenghth of the iron used. In all of these the factors, besides those mentioned, are included in the factor of safety or in an added constant.

WHAT WE MUST HAVE.

1. The requirements of efficient manufacture.

2. The requirements of withstanding reasonably careful transportation and handling.

3. A bursting strength sufficient to withstand the *maximum* pressure to which the pipe will be subjected in service, said pressure being the sum of the maximum ram or water hammer and the static head.

These are the recognized requirements of a proper pipe for water-works use. The requirements, 1 and 2, may be said to have been pretty well determined by experience in the manufacture and handling of cast-iron pipes used for gas. As before stated, Mr. Baermann has prepared a table derived from this and other data.

One criticism that might be offered on his plan is that different makes of cast-iron differ so greatly in their behavior in the pipe factory and so greatly in their ability to stand shocks that it is hardly fair to make both the following statements of a certain thickness: *This is the minimum thickness that can be safely used*, and *this thickness is strong enough to withstand ordinary strains of manufacture and handling*, no conditions being made as to the composition and toughness of the iron. The condition of 18,000 pounds tensile strength will not insure us against getting iron brittle enough or "dirty" enough to require very careful handling.

Where the cost of transportation is high compared to the cost of iron it might pay to get tougher metal and lighter pipe than we would use under other conditions, or perhaps even to cull the lightest pipe from the run, as is sometimes done.

We now come to the much discussed point of

MAXIMUM PRESSURE.

The question of water ram or water hammer has brought forth from so-called water-works experts a display of ignorance monumental in proportions. In view of the antiquity of water-works engineering it is mournful to have to acknowledge the failure to solve such an important question of hydraulics as water ram, and, worse still, such a dearth of recorded experiments or attempts at solution.

Some writers estimate the maximum at twice the static pressure for use in a pipe formula for all conditions of service, others use a greater ratio, while others again say, let the ram be taken care of by the ordinary factor of safety.

Let us assume the ram to be known, and draw up a formula for the proper thickness of pipe:

$$t = \frac{S\,(R + H)\,D}{2\,f} + .125$$

When t = average thickness in inches of the lightest pipe to be accepted.

When D = diameter of pipe in inches.
" H = static pressure in pounds per square inch.
" R = maximum ram in pounds per square inch.
" S = factor of safety.
" f = ultimate tensile strength of iron in pounds per square inch.

.125 is added to allow for a reasonable movement of the core in casting. When the core of a pipe is more than ¼ inch out of centre the pipe should be rejected.

Take $s = 6$ and $f = 18{,}000$, then

$$t = \frac{(R + H)\,D}{6{,}000} + .125$$

This being the average thickness for the minimum weight pipe, we should add 5 per cent. or less allowance for variation in weight to get the average thickness of the pipe to be bought. Whenever this formula gives a result below the minimum thickness prescribed by requirements 1 and 2 the latter thickness should be used.

In view of the fact that R will be difficult to determine with precision, even with the best of formulas, on account of the usual data not being precise, we will let R_1 = the calculated ram, and change our formula to suit. As the ram is in the nature of an intermittent load, a larger factor of safety should be allowed to it than to the static pressure. The following form then might be considered safe:

$$t = \frac{S\,(2\,R_1 + H)\,D}{2\,f} + .125$$

Taking $S = 6$ and $f = 18{,}000$

$$t = \frac{(2\,R_1 + H)\,\mathrm{D}}{6{,}000} + .125$$

This formula should be safe when the results do not fall below the minimum thickness prescribed by the requirements of manufacture and handling. We are now ready to use R_1 if we can get it.

In the year 1884 Mr. Weston* made a valuable series of

EXPERIMENTS ON RAM.

using two systems of pipes, each containing pipes from one inch to six inches in diameter. He used a quick shutting valve and a steam indicator for measuring the ram. Velocities were determined by direct measurement of the water discharged. In the paper recording his results he gives tables and graphical diagrams. The inference derived from these is that the ram is directly proportional to the velocity of flow, approximately speaking, where other conditions are the same.

Table A, columns 1, 2 and 5, shows some of the results obtained by the experiments in the two pipe systems, the ram observed at the point nearest to the quick-shutting valve being taken in each case.

I have calculated the kinetic energy E of the water moving in the system for each experiment, as shown in column 3 of the table. Column 4 gives the square root of E.

Plate IV. gives a graphical representation of the relation of the $\sqrt{E}$ to the observed ram. Plotting $\sqrt{E}$ as abscissa, and observed ram as ordinate, we get for each system a slightly curved line not deviating far

* See Am. Soc. C. E. Trans., 1885.

from a straight line through the origin. The observed ram ranges from 15 pounds to 177 per square inch. The lines given by the two systems, though similar, do no coincide.

We see by the diagram and Table A, that if we take the ram to be directly proportional to $\sqrt{E}$ we shall not be very far wrong within the range of the experiments. The experiments appear to have been, unfortunately, based on some other hypothesis, as, otherwise, a less complicated pipe system would have been chosen, and the results have been, in consequence, more easily interpreted.

Table B and Plate V. show the results obtained in some experiments made by the writer in the meter testing room of the City Water Department. An indicator not being available, the following test was made to ascertain if an ordinary spring pressure gauge might be used to observe the ram. The gauge selected was of the Schaefer & Budenburg make, reading up to 300 pounds. It was carefully tested by a mercury gauge and a table of corrections made out. The gauge was then connected to a 2-inch iron pipe with a small plug cock in the connecting pipe, and

1st. Cock was shut and the 2-inch pipe was filled with water at a pressure of 46 pounds per square inch, the gauge still standing at 0.

2d. The cock was opened quickly, and the movement of the index watched.

This test was repeated a number of times and developed the facts :

1st. That the movement of the index was almost instantaneous.

2d. That the index never passed the 50 pound mark, *i. e.*, its momentum never carried it more than four and usually but two pounds past the point of actual pressure. As the movement of the index was fully as rapid as in any observed case of ram, and much more rapid than in the majority of cases, the inference is that the gauge was quick enough to record the maximum pressure and that the inertia of its moving parts was not great enough to cause it to read much too high in the case of a ram.

The experiments in the meter-room were made to determine the relation between the ram and the velocity when other conditions were unchanged. The comparative velocity or discharge was determined by running off about 10 cubic feet of water, noting the time of discharge and then weighing the water to determine the exact quantity discharged during the time noted.

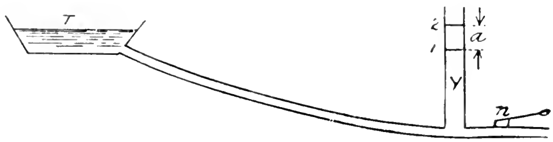
A QUICK SHUTTING VALVE

was used to make the ram, and it was operated as uniformly as possible. Two gauges were used, gauge *B* at the quick shutting valve and gauge *C* about ten feet distant and next to the air chamber, which consisted of about 4 feet of 4 inch pipe. In passing from *C* to *B* the water flowed through besides some pipe about 4 feet of heavy hose and a Crown meter. The supply came through about 50 feet of 3-inch pipe from a 6-inch main. The openings used to regulate the discharge were circular holes in thin copper plates. The ram was obtained by observing the maximum reading of the gauge. This was done with difficulty with the larger rams only.

Five different openings were used, and the experiment repeated a number of times with each.

As may be seen in Plate V. these observations seem to indicate that the ram is nearly directly proportional to the velocity when other conditions remain unchanged, and a quick shuttling valve is used. This would appear to confirm our deductions from Mr. Weston's experiments.

That the ram with a quick shutting valve should be nearly proportional to the square root of the kinetic energy is not surprising when we analyze the problem. Take a case as shown in diagram:



T is a tank, $T\ n$, a pipe. Y, a stand pipe, n, a valve.

Let S = area of cross section of stand pipe.

Let w = weight of one cubic foot of water.

When the valve n is open, the water in the stand pipe stands at 1: when n is closed the ram elevates the water in Y to the point 2. The work done in raising the column of water to that height =

$$E_1 = a\,S\,w \times \frac{a}{2} = \frac{S\,w\,a^2}{2}$$

The kinetic energy in the moving water while n is open —

$$E = \frac{W\,v^2}{2\,g}$$

When W = the weight of all the water in motion. E_1 must be equal to E, hence

$$E = \frac{W\,v^2}{2g} = \frac{S\,w}{2}\,a^2 \text{ and}$$

$$a = \sqrt{\frac{2}{S\,w}\,E}$$

or a is directly proportional to $\sqrt{E}$. a reduced to pounds per square inch would be the ram observed at the foot of the stand pipe.

If instead of taking a stand pipe, we assume that all the energy is absorbed in stretching the pipe, the same method of proof may be used to show that the ram would be nearly proportional to the $\sqrt{E}$. With an air chamber, however, the result should be different.

We now come to the ease of ram with

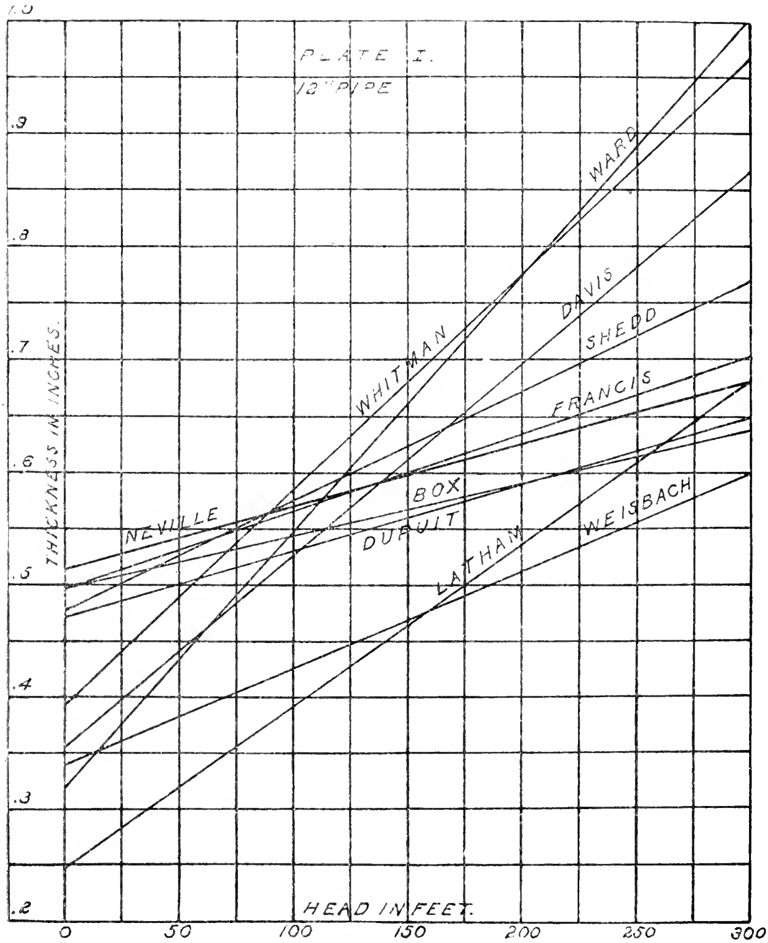
SLOW SHUTTING VALVES.

Table C and Plate VI. show the values and results obtained by experiments made in St. Louis within the past year. The same gauge was used as in the meter room experiments. In each case a line of pipe was selected which was connected at one end to a larger main and had no other connection. After seeing that no air was contained in the pipe, a fire-plug was opened on the line, the height and length of the jet noted and then the plug closed quickly at a rate as nearly uniform as possible. The ram was measured by the gauge set on the next fire-plug farther from the connection.

The height and length of the jet were used to estimate the quantity of

water discharged per minute.* After repeating this experiment a number of times another fire-plug was operated, etc.

The Bell Avenue line was a 6-inch main taken from a 12 inch. The Lindell Avenue line was a 12-inch taken from a 36-inch main. The Bellefontaine road line was a 6-inch taken from a 12-inch main. The Delmar Aveuue line was an 8-inch taken from a 12-inch. The Lafayette Avenue line was a 6-inch taken from a 20-inch main.



In trying to formulate the observed values I first found that for each line, when taken by itself, the average ram is, approximately speaking, directly proportional to the product of the quantity of water discharged per minute by the length of the pipe. measuring from the connection to the fire-plug operated.

Comparing the 6-inch line with the 12-inch, I found that when the

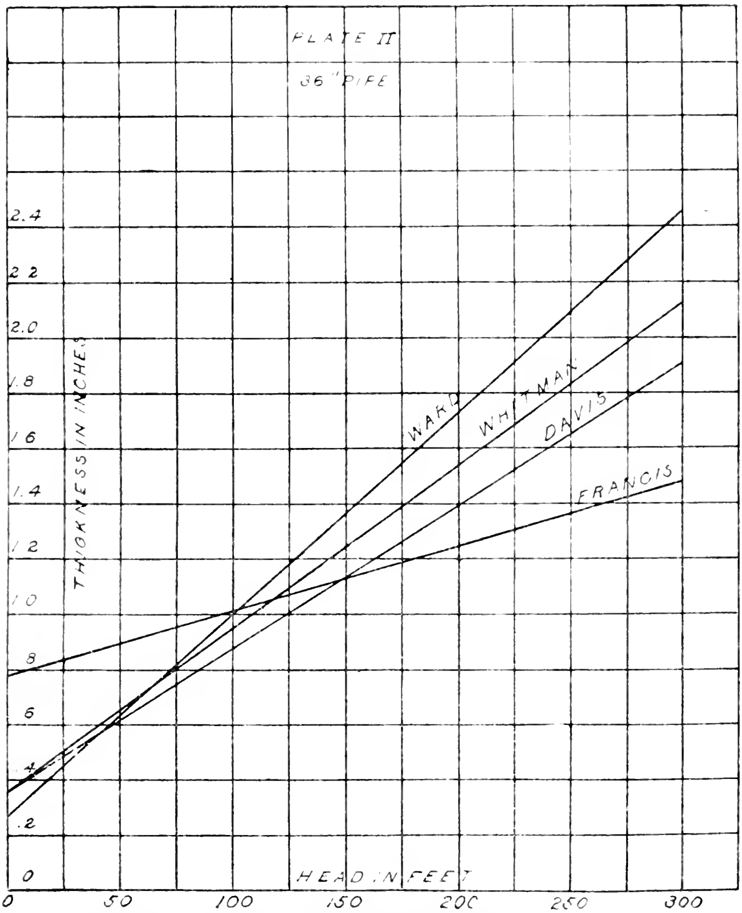
*See Journ. Ass. Eng. Soc., June, 1886, *The Efficiency of a Pipe System, etc.*

product of the quantity per minute by the length was the same, the ram seemed to be inversely proportional to the 4th power of the diameter.

Comparing two 6-inch lines under different static heads, I found that when the product of discharge by length was the same the average ram seemed inversely proportional to the square root of the static head.

Combining these relations we get for an empirical formula:

$$R_1 = \frac{1.2\, q\, l}{D^4 \; H^{\frac{1}{2}}}, \text{ when}$$



q = gallons discharged per minute from fire-plug.

l = length of line in feet measuring from connection, with large pipe to fire-plug operated.

D = diameter of pipe in inches.

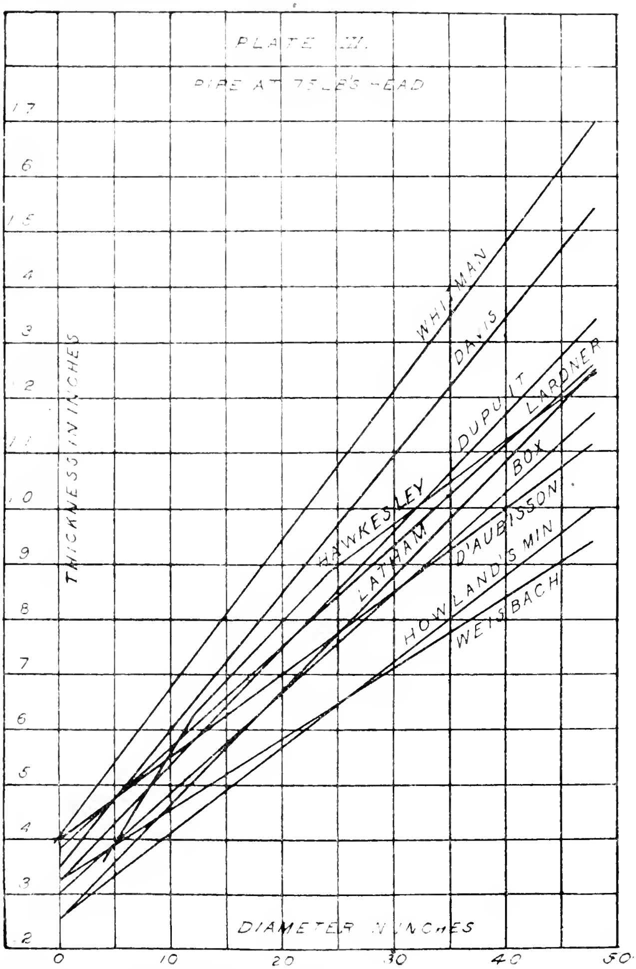
H = static head at plug operated in pounds per square inch.

R_1 = average observed ram or maximum pressure, less the static pressure, in pounds per square inch.

The above formula must be understood to represent only an algebraic

expression of the average results of the experiments made, as unfortunately they were not sufficient in number to warrant their use as a basis for a theory.

In Pl. VI. the formula is represented by a straight line through the origin at an angle of 45° with the axes. The point for each experiment is found by laying off the ram as calculated by the formula as an abscissa, and the average observed ram as an ordinate.

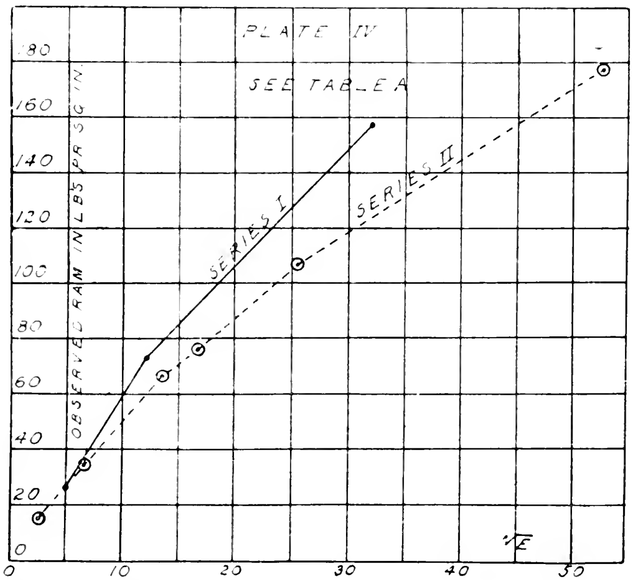


It will be noticed that two of the pipe lines give points falling wide of the formula line. There are reasons why these lines do not disprove the formula. In the case of Delmar Avenue, the line operated was an 8-inch pipe, which received its water through two long lines of 12-inch. Part of the observed ram may then have been due to the long lines of 12-inch. In the case of the Bellefontaine road, the fire-plugs were of a different pattern from those used on the other lines. The valve stems of these

plugs had a screw of 7 threads to the inch, while the valve stems of all the other plugs used had a screw of only 4 threads to the inch. We see that the valves on the Bellefontaine road were necessarily closed more slowly than the others, and the ram was smaller in consequence.

Column 10. Table C, gives the difference per cent. between the ram as calculated by the formula and the average observed ram.

The expression $\frac{1.2\,q\,l}{D^4\,H^{1/2}}$ in part conforms to our preconceived ideas, but in part only. It was to be expected that q and l would appear in the numerator. That D should appear in the denominator is not surprising, but that it should be to the 4th power is quite so. $H^{1/2}$ appearing in the denominator is also unexpected. We see that the formula is quite different from that deduced from Mr. Weston's experiments with a quick shutting valve.



In the above experiment very rough methods were used. Rough methods, however, would be little objection for this work, could enough experiments have been made to have equalized the errors. Great precision in work of this nature is unnecessary, as in using our formula after we have derived it we must always work with data which are not precise. For example, if we wish to compute the ram at a given point in an imaginary pipe-line to be connected with our system, l and D are the only quantities which are known precisely, as H will fluctuate from hour to hour and from day to day, and q must be calculated from data more or less unknown by some formula not infallible.

Not being in position to pursue my experiments further at present, I desire to put them on record for what they are worth. A great many experiments must be made before the problem of ram can be fairly handled. If each one, however, who has the facilities for making a few

experiments will give some of his time and energy to the cause, much may be done. Let him lay out his work with method, eliminating as many factors as possible from each series of experiments, the better to determine the remaining ones, and record his experiments in the most proper manner.

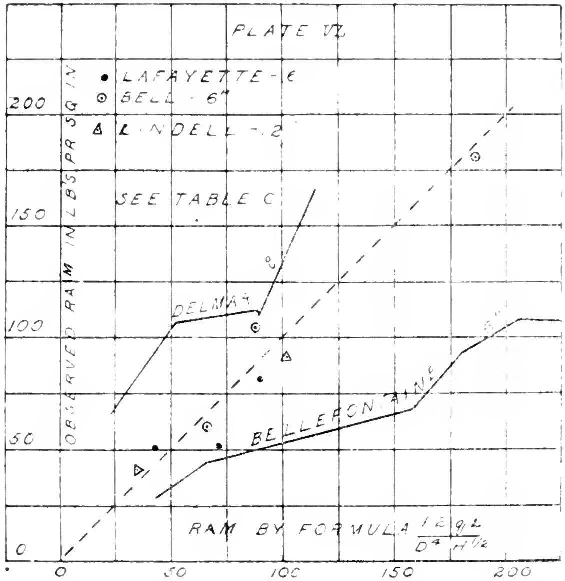
Assuming the formula derived from my experiments to be correct, it will only be true for the particular form of fire-plug used with a 5-inch valve and a 3-inch nozzle.

Fire-plug manufacturers who use the gate-valve claim that the ram is less with the gate than with the plug valve, and they are probably right.

The fire-plug gives or should give about the maximum ram to which city mains are subject, as private consumers will seldom draw through one opening the size of a fire-plug nozzle. The rams produced when a main is filled in an improper manner after making connections or repairs, may be much greater than that given by closing a fire-plug. These

rams may, however, be kept within any required limit by the proper proportioning of air vents, etc.*

If, then, our maximum ram is to be produced by the fire-plug, should not great attention be given to fire-plug rams? If it be true that a gate-



valve hydrant will give less ram than a plug-valve hydrant, why not use a lighter pipe where the former is in service?

If a 3-inch hydrant nozzle will give more ram than a $2\frac{1}{2}$-inch nozzle, as we have every reason to suspect, why not use lighter pipe with the latter than with the former? Some day, perhaps, we shall have a co-efficient determined for each form of fire-plug to be used in our ram formula.

All the experiments mentioned in this paper were with lines supplied from one end only. When we have mastered these it will be well to investigate lines supplied from both ends, then lines of varying cross section, etc. Lines supplied from one end are, however, first in importance, as in a city pipe system usually at least half of the pipe lines when first laid are supplied from one end only, and are in that condition subjected to their hardest treatment. Later on they are probably connected up by cross lines and the rams lessened in consequence.

Until more experiments have been made, we may fairly make the following assumptions as to the ram in pipes supplied from one end:

I. If the diameter of pipe and the fire-plug be given, the greater the length of line the greater the ram, within the limit of lengths of dead-end lines for city use.

II. If the length of pipe and the fire-plug be given, the greater the diameter of pipe the less the ram.

III. If the length and diameter of pipe be given and the fire-plug valve, the larger the plug nozzle the greater the ram.

*See Journ. Ass. of Eng. Soc., August, 1887, *Draining and Filling Mains.*

Comparing these propositions with our true formula for thickness, we see that a pipe which would be perfectly safe under a certain static head in one part of our system may be too light for another part under the same static head. This may in part account for the difference in formulas and the difference in practice in cities and towns.

You may hear an engineer say : "I tried light pipe, but I have come back to the old heavy weights," while another will say, "I can point out several places where light pipe have been used for years with success." Probably neither of these advocates will ever think that the static pressure is not the only variable in the conditions of a city pipe.

I remember a case on Papin street, in this city. Several years ago the line in question was a "dead-end" and was continually springing a leak in the joints. The street was nearly always torn up at some point by our repair gang. A gauge put on the line showed severe and frequent rams from the service. Some months later the line was extended to reach a new cross-line, so that it should be supplied from both ends. Since that connection we have rarely had a leak in that line. Now the static head was the same under both conditions, and by all pipe formulas the same weight of pipe should have been used in the last arrangement as in the first.

If our experiments have not much misled us, under ordinary conditions the length of a line of pipe of small diameter is more important than the static head in determining the maximum pressure. Is it not then time that we take the length of a line into account in estimating thickness of pipe?

Although it would hardly be proper to deduce a formula from the experiments herein described, we may keep the following points in mind when choosing our pipe :

The farther from the reservoir or stand pipe we get the heavier our pipe should be, other things being the same.

Small pipe should have a greater *proof* strength than large to have the same factors of safety when used under the same conditions.

In connection with this, it may be said that large pipe should have a

TABLE A.—RAM WITH QUICK CLOSING VALVE.

	Diameter of opening in inches.	Velocity of flow in 6-in. pipe, in feet per sec.	Kinetic energy.		Observed ram, in lbs. per sq. in.		
	1	2	3	4	5	6	7
		v	$E=\Sigma Wv^2$	$\sqrt{E}$	R	$\frac{R}{\sqrt{E}}$	
Series I.*	⅛	.0294	25.04	5.0	26.9	5.38	6 in. pipe, 111.3 ft.
	3-16	.071	146.1	12.08	72.8	6.03	2 " 58.4 "
	¼	.15	652.1	25.53	129.3	5.06	1½ " 99.3 "
	5-16	.188	1,023.1	32.	158.7	4.96	1 " 4. "
Series II.*	⅛	.0288	6.834	2.61	15.	5.75	6 " 181.3 "
	3-16	.074	45.26	6.73	35.	5.20	4 " 65.5 "
	¼	.15	185.16	13.60	66.7	4.90	2½ " 3.5 "
	5-16	.19	284.7	16.87	76.1	4.51	2 " 1.1 "
	⅜	.28	645.5	25.4	106.3	4.26	1½ " 6.6 "
	½	.58	2,768.6	52.6	177.5	3.37	1 " 5.8 "

*In this series the water flowed through the above pipes in the order given in Col. 7.

greater factor of safety on account of its greater importance, but admitting this, the difference in factor of safety will hardly be chosen great enough to balance the great difference in ram, so that the proof strength of small pipe will usually be greater than that of large as required by the older formulas, and not as Mr. Baermann would have it.

The larger our fire-plug nozzles or other openings, the heavier our pipe should be, and we should also take into account the rapidity with which the openings are to be closed.

In designing pump mains the length and *changes in velocity* of flow are of as much importance as the static pressure.

If these propositions be true, in choosing our water pipes we should not follow blindly any of the present established formulas. Until a better one is derived, we may, by tempering our formula with intelligent judgment, gain in both saving and safety.

TABLE B.—RAM WITH QUICK CLOSING VALVE.

Diameter of opening in inches.	No. of experiments.	Water discharged in cu. ft. per sec.	Average ram at gauge *B*, in lbs. per sq. in.	Average ram at gauge *C*, in lbs. per sq. in.
1	2	3	4	5
2	6	.304	72	54
$1\frac{1}{4}$	5	.243	70	56
$\frac{3}{4}$	6	.149	49	34
$\frac{1}{2}$	5	.072	22	13
$\frac{1}{4}$	4	.020	6	2

N. B.—Ram is taken as maximum pressure, less static pressure.
Static pressure *B*, ; 41 lbs. *C*, 51 lbs.

TABLE C.—RAM WITH SLOW-SHUTTING VALVE.

Street.	Fireplug No.	Diameter of pipe.	No. of experiments.	Quantity of water discharged in gallons per min.	Length of pipe in feet from connection to fire-plug running.	Static pressure in pounds per sq. in.	Ram by formula.	Average observed ram.	Difference. $R - \frac{1.2\,q\,l}{D^4 H^{\frac{1}{2}}}$	
	1	2	3	4	5	6	7	8	9	10
		D		q	l	H	$\frac{1.2\,q\,l}{D^4\,H^{\frac{1}{2}}}$	R	lbs.	per cent.
Lafayette.	0	6	6	600	30	12	5	5±	......	......
	1	6	4	510	300	10	44	50	6	14
	2	6	5	340	650	8	72	51	—21	—29
	3	6	5	240	980	6	90	81	—9	—10
Bell.	2	6	9	910	500	10	66	60	—6	—9
	3	6	5	840	720	40	88	104	16	18
	6	6	7	580	2070	36	187	180	—7	—4
Lindell.	4	12	4	1400	3150	52	35	41	6	17
	9	12	6	1210	8600	35	102	92	—10	—10
Bellefontaine.	1	6	3	650	570	64	43	28	......	......
	2	6	3	520	1080	64	65	44	......	......
	7	6	4	330	4320	68	159	69	......	......
	8	6	4	340	4720	68	179	93	......	......
	9	6	4	360	5150	69	206	108	......	......
	10	6	7	370	5700	74	226	107	......	......
Delmar.	1	8	4	1210	435	40	24	66	......	......
	2	8	5	1140	930	35	52	106	......	......
	3	8	4	960	1785	32	89	112	......	......
	4	8	4	880	1890	29	90	109	......	......
	5	8	4	730	2640	24	115	166	......	......

N . B.--Ram is taken equal to maximum pressure less static pressure.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JANUARY 16, 1889:—A regular meeting was held at the Society's rooms, Boston & Albany Railroad Station, Boston, at 19:30 o'clock, President Fitzgerald in the chair, thirty-nine Members and nine visitors present.

The record of the last meeting was read and approved.

Messrs. Arthur G. Fogg, Henry M. Howe, Walter H. Richards and Walter S. Whiting were elected Members of the Society.

Mr. William O. Webber, Brookline, Mass., was proposed for membership by A. W. Locke and Desmond FitzGerald.

The Secretary read a letter from the Engineers' Club of Kansas City, inviting an expression of the views of the Society upon the advisability of providing means for the transfer of Members from one local engineering society to another, on change of residence. The letter was referred to the Government to report its recommendation at the next meeting.

The Secretary presented for the Government recommendations that the annual dinner and the annual meeting be held on different evenings, and that a committee be appointed to consider the advisability of revising the Constitution.

On motion of Mr. Fuller, the first recommendation was adopted and it was voted to appoint a committee to arrange for the annual dinner, to take place on the second Wednesday in March. Mr. Henry Manley was appointed as that committee, and the sum of $50 was appropriated for the general expenses of the dinner and placed at his disposal.

On motion of Mr. Tilden, the second recommendation of the Government was adopted and the President was authorized to appoint a committee of five to consider if any changes in the Constitution and By-laws are advisable and to obtain the views of the Members of the Society.

The President named as that committee Messrs. F. P. Stearns, S. E. Tinkham, E. H. Lincoln, G. F. Swain and H. M. Howe.

On motion of Mr. Freeman, the Treasurer was authorized to pay $4 of the entrance fee of those who were formerly Members of the Society and resigned in good standing, this to apply only during the current year.

The Secretary then read, in the absence of the author, a paper entitled "Duty Trials of Pumping Engines; a Plea for a Standard Method of Conducting Them," by Mr. George H. Barrus. Mr. J. A. Tilden discussed the paper briefly and Mr. J. E. Cheney gave a short account of the method pursued at the duty trials of the new pumping engines at Chestnut Hill. The subject was further discussed by Messrs. Coggeshall, Fuller and Stearns.

[*Adjourned.*] S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

JANUARY 2, 1889.—299th Meeting.—The Club met at Washington University at 8:10 P. M., President Meier in the chair, forty Members and four visitors present. The minutes of the 298th meeting were read and approved. The Executive Committee reported the doings of its 63d meeting, approving the applications for membership of F. W. Abbott, L. Bartlett, O. W. Ferguson, A. N. Milner, L. Parker and H. R. Stanford. They were balloted for and elected.

An application for membership was announced from Edward F. Wall, of the City Water Department. His indorsers were W. W. Penney and M. L. Holman.

Mr. Robert Moore then read the following:

St. Louis, January 2, 1889.

To the President and Members of the Engineers' Club of St. Louis:

Gentlemen: Your Committee appointed in May last to co-operate with the Kansas City and other engineering clubs in their efforts to prevent the further construction of unsafe highway bridges, having considered the communications from the Engineers' Club of Kansas City (dated May 14, 1888), from the Western Society of Engineers (dated June 13, 1888) and from the Indiana Society of Civil Engineers and Surveyors (dated June 19, 1888), which have been referred to them, beg leave to report:

That these communications ask for an expression of opinion by this Club upon various propositions or suggestions, which are in substance as follows:

1. That the supervision and inspection of highway bridges should be placed in the hands of a State engineer.

2. That the law should establish certain standard general specifications for such bridges.

3. That in order to facilitate the employment by county boards of engineers to prepare plans and specifications for highway bridges, a scale of charges for such work, similar to that in force among architects, should be adopted by the engineering clubs.

4. That a convention of delegates from various engineering clubs should be held to consider and act upon these and other propositions looking to the construction of better highway bridges.

Taking up these propositions in order, it is the judgment of your Committee, that no improvement upon the present vicious methods of highway bridge construction can be looked for until such bridges are brought under the supervision of skilled engineers acting on behalf of the public. But under the conditions actually found in all the Western States, the only practical way to secure such skilled supervision is to place work of this kind under the general charge of an engineer or engineers appointed by the State. To expect that county boards will of themselves place work of this kind in competent hands is in the great majority of cases an utterly delusive hope. The requirements for such work are so poorly understood and appreciated by such boards that the adviser whom they would select would be the cheapest man or the one most favored by local influences rather than the most competent. Moreover, the cost of really skilled advice and supervision can be made less onerous if the counties act together as a state than is practicable by independent action—a consideration of much importance to the poorer communities.

As regards the scope of the State engineer's control, we think it would be well to provide that the plans and specifications of all bridges exceeding a certain span should be subject to his approval before erection and that for all the more important structures he should appoint a competent inspector to see that the plan is faithfully carried out, this inspector to be paid by the counties for whom the work is done.

We should also make it the duty of the State engineer to at once examine into and report upon the causes of all failures of highway bridges, and, whenever possible, locate the responsibility, such reports to be promptly published in full in the local newspapers. The certainty of such examination and publicity would of itself prevent many of the grosser frauds which are now practiced with impunity by unscrupulous contractors and be a strong stimulus to vigilance on the part of those in another city.

If competent supervision of the kind indicated be provided by the State, we doubt very much the propriety of enacting by law any general or standard specifications applicable to such work. The requirements of different locations are so

unlike and the art of bridge building is in such a formative and growing state that any stereotyped requirements would be likely to work harm rather than good. It would be better to leave all such matters to the judgment of the engineer, who can, if he chooses, adopt general standards for his own convenience and the guidance of others, but will be free to change them as the teachings of advancing knowledge and experience shall dictate. With full responsibility laid upon him he is much more likely to be over cautious than to be over bold, and there is little danger that the public safety will suffer.

That the general adoption by engineers of a scale of minimum charges for the preparation of bridge plans and specifications and the supervision of the work, as suggested in one of the communications referred to us, would be a matter of great convenience to the engineers themselves, and greatly facilitate the employment of experts by the counties and towns, we very fully admit. At the same time, we think that the number of members of the various engineering associations who have any special experience or interest in bridge work is so small that these associations are not in a position to act intelligently upon a matter of this kind nor justified in acting at all. Action of this sort, moreover, at this time by these associations would favor the belief that the chief object of the present movement was professional compensation rather than the public safety, and thus deprive it of the public sympathy and support which is essential to success. We think, therefore, that any action upon this matter should be confined to those who are specially interested, and that the clubs, as such, should do nothing at all.

The suggestion that there should be a conference of representatives of various engineering societies, with a view to some united recommendation to the State Legislature, seems to be a good one, and if such a conference be called by either of the clubs which have taken interest in this subject, this Club should be represented in it. Respectfully submitted,

ROBT. MOORE,
C. H. SHARMAN, } Committee.
A. W. HUBBARD,

On motion of Mr. Perkins this report was received and the Committee discharged. On motion of Prof. Johnson the report was adopted as the sense of the Club.

Mr. R. E. McMath called attention to the desirability of collecting and contributing engineering publications for the benefit of the Club's library.

Mr. N. W. Eayrs then read a paper on the "Interlocking System of the St. Louis Bridge and Tunnel Railroad." The present system had been in use since 1883. Three stations were operated, one large one in East St. Louis and two smaller ones in this city. An air compressing plant was operated at the east pier of the bridge. The compressed air was carried to the three stations, where it was used to operate pumps, which maintained a pressure on a second system of pipe work, by means of water in the summer, and a solution of chloride of calcium in the winter. A detailed description was given of the workings of the different parts of the system. There was no loss of fluid, except by leakage, which was small. Messrs. Bartlett, Holman and Sharman participated in the discussion

Mr. Thos. McMath then presented a paper on the "Peculiarities of the Citizens Cable Railway." This system is quite extensive, some twelve miles being operated, in three sections. The paper gave an interesting description of the various types of grips in use, also the dies and the material of which they should be made; method of taking and letting go the cable; also a description of the cable itself, and the method of taking care of it. An explanation was given of the difficulties that had been met with, and how they had been remedied. The author described some improvements of his own which were in successful use. The paper was illustrated by drawings and models. Messrs. Bartlett and Bryan took part in the discussion.

In the general discussion, Mr. Wise, of the city sewer department, exhibited a

specimen of wood which had been found at a depth of 37 feet in good clay on Sarah street. The specimen was undoubtedly of great antiquity. Mr. Holman exhibited the bottom of a cast-iron meter which had been buried in the earth for eleven years in front of the car stables, 1,827 Market street. It had become so soft as to be easily whittled. He was unable to explain the cause of this rapid deterioration. Water pipe would no doubt be affected in the same manner. The decay might have been caused by a gas leak or the presence of foreign matter in the soil.

[*Adjourned.*] WM. H. BRYAN, Secretary.

JANUARY 16, 1889: 300th Meeting—The Club met at Washington University at 8:15 P. M., twenty-three Members and three visitors present. Both the President and Vice-President being absent, the meeting was called to order by the Secretary, and Robert Moore elected Chairman. The minutes of the 299th meeting were read and approved. Application for memberships were announced as follows: Henry Groneman, of the Bridge Department of the city, indorsed by Carl Gayler and Max G. Schinke; Nils Johnson, of the Water-Works Extension, indorsed by M. L. Holman and J. A. Laird. The Committee on Permanent Quarters for the Club reported a proposition from the Public School Library. One from the Mercantile Library was expected before the next meeting.

The Secretary read a letter from the Secretary of the Engineers' Club of Kansas City, calling attention to the desirability of providing for the transfer of Members from one Society to another on change of residence. The question was discussed by Messrs. Johnson, Bryan, Moore, Seddon and Smith. On motion it was ordered that the consideration of this matter be made the special order for the next meeting, February 6th. Mr. Carl Gayler then read a paper on "Wrought-iron and Steel Eye-bars," calling attention to the difference between European and American practice. He showed how, by the use of the testing machine, the form of the eye-bar had been greatly improved. He described the standard forms in use, and their method of construction. He showed that it was not safe to consider the strength of the complete eye-bar as great as that of the bar proper. Wrought iron eye-bars had had their day, and steel was now the metal almost universally employed. The two difficulties to be guarded against were overheating and an excess of phosphorus. The process of annealing was of benefit. The writer had recently tested twenty steel eye-bars, full size, and the results were surprisingly good. The discussion was participated in by Messrs. Johnson, Wheeler, Seddon and Moore. It was shown that while the manufacturer might demand of the mills certain chemical proportions, the engineer need not do so, as he wanted only physical results. It was shown that in piling the wrought-iron plates for making the head of eye-bars, care must be taken in placing the plates so that the fiber was parallel to that of the bar itself. This fiber was always in the direction of the rolling.

The Secretary then read a paper by Prof. A. E. Phillips, of Lafayette, Ind., on "A Burr Truss." As no drawings accompanied the paper, Mr. Hubbard made a sketch of the typical truss in question. The paper was descriptive of a bridge near Lafayette, Ind., and gave the results of an examination into its condition, which showed it to be dangerous. The author's conclusion was that it should be replaced by a safe and more substantial structure. The discussion proved quite interesting. Mr. Smith told of a similar bridge over Mill Creek, Cincinnati, which had been used for many years, and was now in good condition. The arch was of beechwood, firmly built into the masonry. Mr. Moore mentioned a wooden bridge which to his knowledge had stood nearly fifty years. In his opinion their long life was due to the fact that the assumed load was never reached. Mr. Gayler mentioned bridges in the old country over 100 years old. Parts showing the slightest deterioration were immediately replaced, by which method it was possible to maintain them indefinitely.

Mr. Hubbard spoke of the difficulty of calculating strains. Mr. Seddon said that possibly the elasticity of wooden bridges permitted them to stand shocks better than iron. Professor Johnson gave some of the characteristics of wooden members.

The Secretary read a memorial to the State Legislature of Missouri and the draft of an Act to Promote the Safety of Bridges, which had been prepared by the Engineers' Club of Kansas City.

On motion, it was ordered that a committee be appointed to draw up a memorial to the Legislature indorsing the bill. Messrs. Seddon, Johnson and Gayler were appointed such committee.

[*Adjourned.*] WM. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

JANUARY 8, 1889:—The Annual Meeting (254th of the Society), was held at Weber's restaurant, No. 66 Washington street, at 5 o'clock P. M., President Gottlieb in the chair. About forty Members were present.

The minutes of the last meeting were read and approved, after the Secretary had announced that one of the nominees for President, Mr. Chas. L. Strobel, had withdrawn his name, and so notified the Members, and that the nominee for Treasurer, Mr. E. C. Carter, was unable to serve, and the name of H. W. Parkhurst had been substituted.

Ballots were then called for from those who had not voted, and the following tellers appointed to canvass the vote: Messrs. Williams, Artingstall and Carter.

The resignation of Mr. G. R. Bramhall, Chicago, and of Mr. E. T. Blake, St. Joseph, Mo., were received and accepted.

The following were proposed for membership:

Mr. A. D. Whitton, Chief Engineer, U. S. Construction Company, Chicago: Mr. L. L. Wheeler, U. S. Assistant Engineer, Improvement Illinois River, Chicago; J. H. Flagg, Assistant Engineer, Survey Illinois River, Chicago.

The Secretary stated that he had received several communications in regard to the inequity of the present dues, as between resident and non-resident members. and in response thereto, he submitted the following amendments to the By-Laws, Article V.:

ARTICLE V. AS NOW IN FORCE.

SECTION 1. The entrance fee shall be five dollars ($5); said amount to accompany each application for admission and to be returned if applicant is rejected.

SEC. 2. Members residing in Cook County shall pay dues at the rate of eight dollars and fifty cents ($8.50) per year. All other members, of every grade, shall pay at the rate of seven dollars and fifty cents ($7.50) per year.

SEC. 3. All dues shall be paid to the Secretary semi-annually, on or before the first regular meeting in January and July of each year.

PROPOSED AMENDMENTS OF SECTIONS 2 AND 3.

SECTION 2. Members residing in Cook County, Illinois, or having a permanent place of business in the city of Chicago, shall pay dues at the rate of ten dollars ($10) per year. All other members, of every grade, shall pay at the rate of five dollars ($5) per year.

SEC. 3. All dues shall be paid to the Secretary, and are payable on or after the annual meeting in January of each year.

Mr. D. C. Cregier submitted amendments to Article V. by adding the following sections:

SEC. 4. Any Member who has paid annual dues for a period of twenty years consecutively, shall thereby become a Life Member, and thereafter be exempt from the payment of annual dues, and shall be entitled to such membership certificate, signed by the President under the seal of the Society, attested by the Secretary.

SEC. 5. Life Members shall be entitled to exercise all the rights and privileges prescribed for full Active Members, and shall be subject to all the provisions of the By-Laws of the Society, except as herein provided.

These amendments were laid over, under the rules, for discussion at the next meeting.

The report of the officers being in order, the retiring President, Mr. Gottlieb, spoke informally in regard to the work of the year. He referred to the change in quarters, which was a necessity, but which had not been an improvement, and hoped that something definite might be done in providing better arrangements during the coming season. The matter had been referred to the Trustees, and he as one of them had endeavored to obtain some consideration and action in regard to it, but had not met the encouragement which the situation had called for. He thought the society could popularize its work in many ways; that its meetings might partake of a more social character, and that more attention should be invited from the press.

The Vice-President, Mr. Weston, also spoke informally in the same direction.

The Secretary submitted his annual report, as follows:

ANNUAL REPORT OF SECRETARY FOR 1888.

Including the annual meeting at the beginning of the year, eleven meetings have been held. The present membership is 191, as follows: Members, 187; Juniors, 1; Associates, 2; Honorary, 1. The number elected during the year was 14, the number of resignations 15 and deaths 3. A large proportion of the resignations were from non-residents who have joined other societies of the Association.

The receipts from all sources have been $1,466.89, and about $300 is due and remains uncollected. This delinquency is most largely in the special assessment of $2.50 authorized as an increase in dues by amendment to By-Laws in March last, and ordered collected in June. The receipts virtually cover all obligations for the year. A detailed exhibit of receipts and expenditures will be presented by the Treasurer.

In May last, the Society was compelled to change its quarters to less desirable ones, and it has not been practicable since to hold the meetings at the regular time provided in the By-Laws. Notwithstanding this, however, there has been a gratifying increase in attendance and interest at meetings.

During the year much interest has been exhibited in a permanent home for the Society, a place always open to members, the library and exchanges fully available for use, with the Secretary or an attache in attendance. The matter was referred to the Trustees, but no action has been reported. It is believed that it will be practicable to unite with the Architects for such an object.

If another hundred members are added to the Society it will provide a return of $2,500, which will probably be sufficient to inaugurate this change. With such a purpose in view, a systematic effort will no doubt secure the necessary arrangements before the first of May. The material for a society of 400 to 500 members is available, and no doubt the growth will be rapid and the Society home made correspondingly beneficial. It is a question for early consideration.

The work of the Society during the year has consisted more largely in the discussion of matters for the advancement of the profession rather than the reading of papers. Three papers have been presented, constituting with the written discussions a collection of 13 papers forwarded for publication. These papers were: "Classification of Materials in Railway Construction," with their discussions; "Levels of the Lakes as Affected by the Proposed Lake Michigan and Mississippi Waterway," with seven written discussions, and "The Necessity of a Determinate Systems of Weights and Measures." In addition to the above, the Society has especially discussed the proposed "Lakes and Gulf Waterway" and the "Re-

organization of National Public Works," and special publications in regard to these topics have been furnished to the members.

At the beginning of the year five standing committees were appointed, viz.: Board of Managers for Association, Finance, Library, National Public Works and Harbors and Waterways. Of these, the Board of Managers has performed its usual duties; the Finance, Library and Harbors and Waterways Committees have made no reports. The Committee on National Public Works has collected moneys, submitted progress reports and co-operated actively with the committees of other societies in promoting the general object of its creation, and will submit a financial statement and report at the next meeting.

The special committee on "Specifications for Highway Bridges" has submitted general progress reports, the matter has been a prominent topic for discussion in the society, and is still under advisement with a view to a measure of legislation. The special committee on "Better Provisions for Rainfall Observation" by the Signal Service submitted a report and were discharged. A committee upon employment has made a report which is now pending and a committee was appointed upon Drafting Material and Scales and still has the matter under advisement.

The Society has memorialized Congress in regard to national public works, and also in regard to better provision for rainfall observations by the Signal Service.

The Secretary records the death of three members during the year: Mr. Chas. Latimer, Wm. L. Baker and Michael McDermott. A committee has reported a suitable memorial in regard to the first two.

The Secretary cannot close without expressing his profound conviction that the circumstances of the last twenty years have profoundly changed the purposes for which our engineer organizations should exist. Formerly, technical instruction and social improvement were the primary aim. The first is now so largely furnished in a multitude of ways that it is no longer a cementing agency, and the conditions of the latter have greatly changed though not diminished in importance. I feel convinced that the one great purpose of professional organization is to promote the status and well being of the profession. The society has already exhibited a gratifying movement in this direction which can be largely multiplied during the coming year.

The Treasurer submitted a statement, as follows:

TREASURER'S REPORT FOR 1888.

Receipts.

Cash balance received from retiring Treasurer	$29.90	
" surplus from Committee on Morehouse Memorial and Supper	16.25	
" received direct from Members for dues	38.00	
" received from Secretary	926.42	
Vouchers received from Secretary	456.32	
		$1,446.89

Disbursements.

Rent of rooms 13 months, including January, 1889	$195.00	
Printing proceedings, etc	76.70	
Insurance of library	32.00	
Paid on account of "Journal"	549.85	
Repairs of book cases	7.45	
Exchange on checks received for dues	.60	
Secretary's salary, 12 months	300.00	
Sundry postage, etc	78.17	
Expense of changing quarters	38.15	
Assessment by Council on National Public Works	25.00	
Balance in hands of Treasurer	163.97	
		$1,466.89

Wm. S. Bates, Treasurer.

Mr. Williams announced the result of the canvass of the vote as follows:

Total number of ballots cast, 75. President: E. L. Corthell, 41; Chas. L. Strobel, 27; L. E. Cooley, 2; R. F. Booth, 1. First Vice-President: Chas. MacRitchie, 38; Hiero B. Herr, 32. Second Vice-President: Samuel McElroy, 42; Horace E. Horton, 26. Secretary: John W. Weston, 73; L. E. Cooley, 2.

Treasurer: H. W. Parkhurst, 73; W. S. Bates, 2. Librarian: G. A. M. Liljencrantz, 74; J. C. Des Granges, 1. Trustee: Chas. FitzSimons, 75.

The President announced the election of E. L. Corthell as President; Chas. MacRitchie as First Vice-President; Samuel McElroy as Second Vice-President; John W. Weston as Secretary; H. W. Parkhurst as Treasurer; G. A. M. Liljencrantz as Librarian, and Chas. FitzSimons as Trustee.

In the absence of the President-elect, the First Vice-President, Mr. McRitchie, was escorted to the chair and the new officers installed. The further proceedings are reported by my successor. L. E. COOLEY, Secretary.

The further proceedings of the evening were entirely of an informal character. Some thirty-seven Members participated in the supper. Speeches were called for from a large number present, who cordially responded, and indications gathered therefrom showed a marked interest in the welfare of the Society, promising immediate results for good.

Mr. Gottlieb moved, which was seconded and unanimously carried, that a supper should be a feature of the regular meeting for April.

[*Adjourned.*] JOHN W. WESTON, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

JANUARY 7, 1888:—The annual meeting of the Civil Engineers' Society was held this evening. President Loweth and fifteen Members present. The minutes of the last meeting having been read and approved, Mr. E. E. Woodman, Right of Way Agent of the Chicago, St. Paul, Minneapolis & Omaha Railroad, was elected to membership. After an address from the President upon the best methods of making the Society useful for the coming year the reports of the other officers for the past year were read.

The Society then proceeded to the election of officers for the coming year, with the following result :

Chas. F. Loweth, President.

S. D. Mason, Vice-President.

Geo. L. Wilson, Secretary.

F. W. McCoy, Treasurer.

A. Munster, Librarian.

The paper of the evening was read by Mr. W. W. Curtis upon "Stand Pipes for Water-Works," illustrated by working drawings of the stand-pipes at Cedar Falls, Iowa; St. Cloud, Minn.

After discussion of the paper the meeting adjourned.

GEO. L. WILSON, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

JANUARY 7, 1889 :—A regular meeting was held in the Club Room at 8 P. M., President Wm. B. Knight in the chair, Kenneth Allen, Secretary. There were present eighteen Members and three visitors.

Minutes of the Annual Meeting and that of the Executive Committee were read and approved.

Mr. Henry Goldmark and Capt. Gerald Bourke were proposed as Members.

On motion of Maj. O. B. Gunn it was voted that the Chair appoint a committee of three to confer with Members, and if thought advisable, to provide for a banquet to be held in the near future. Messrs. Mason, F. W. Tuttle and Kiersted were appointed.

On motion of W. H. Breithaupt, amended by C. W. Hastings, it was voted that the Secretary correspond with other local societies—more especially those of the

Association—to obtain their views as to the advisability of providing for a transference of membership without payment of initiation fees or more than the annual dues of one Society, and to state that the Kansas City Club was in favor of such an arrangement.

The Secretary announced the appropriation of $40 for subscription to ten engineering magazines.

On a canvass of ballots, the following were declared elected:

President, O. B. Gunn.

Vice President, W. H. Breitbaupt.

First Director, Wynkoop Kiersted.

Second Director, S. H. Yonge.

Secretary, Kenneth Allen.

Treasurer, F. W. Tuttle.

Librarian, Frank Allen.

As associate member, Frederick C. Gunn.

The retiring President, Wm. B. Knight, read an address. It was advised to make efforts to enlarge the list of associate Members, and to add associates and honorary Members. The benefit of united action in local societies in bringing about uniform standards, measures, methods of work and legislation was urged. The Club had taken active measures with regard to National Public Works and Bridge Reform, and it was thought much could be accomplished in the conduct of municipal work.

The following resolutions, prepared by C. W. Hastings, were adopted.

Whereas, Mr. Wm. B. Knight, the retiring President, was active in the organization of this Club two years since, and has been since then untiring in his devotion to its interests and in his energy in advancing them ; and

Whereas, We believe that the present encouraging condition of the Club is due to his management and work more than to that of any other individual ;

Resolved, That we desire to and do hereby formally express our gratitude to Mr. Knight for his services in behalf of the Club.

On motion of Kenneth Allen, Mr. Knight was unanimously chosen to represent the Club on the Board of Managers of the Association of Engineering Societies.

The President elect then took the chair, and made a few appropriate remarks.

[*Adjourned.*] KENNETH ALLEN, Secretary.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

LEVELS OF THE LAKES AS AFFECTED BY THE PROPOSED LAKE MICHIGAN AND MISSISSIPPI WATERWAY.

BY GEO. Y. WISNER AND OTHERS *

[Read before the Western Society of Engineers, Sept. 5, 1888, and at subsequent meetings.]

Introductory: The Proposed Waterway.
Levels of the Lakes, etc., by GEO. Y. WISNER.
Discussion, by L. E. COOLEY, L. M. HAUPT, CLEMENS HERSCHEL, J. B. JOHNSON, WM. PIERSON JUDSON, WALTER P. RICE, D. FARRAND HENRY, BENEZETTE WILLIAMS.
Data pertaining to the outflow of the lakes.

Prefatory.

An effect upon the level of the lakes, injurious to navigation, by the turning of a large volume of water across the Chicago divide, has been intimated from quarters not in sympathy with the project for a great drainage and navigation channel from Lake Michigan at Chicago via the Desplaines and Illinois River to the Mississippi, and ultimately to the Gulf of Mexico. These suggestions do not profess to be based upon any technical consideration of the data, but have, nevertheless, been seized upon with avidity by those opposed, for various reasons, to the realization of any such project, and many doubts have thus been raised throughout the Lake region and in the Mississippi Valley, and have even found expression upon the floor of the U. S. Senate.

It has seemed very proper, therefore, that the Western Society of Engineers, as representing the profession most fully in the region in question, should give a preliminary consideration to the matter from the existing data. Accordingly, Mr. Wisner's paper has been laid before the Society and discussion invited from others of long experience upon the lakes or the rivers to be affected by the proposed contribution of water, or those expert in kindred hydraulic problems. The oral discussions have been of much interest, but have not been reported. The several papers submitted, together with matter germane to the question, are herewith compiled and publication authorized by order of the Society.

*Compiled and edited by L. E. Cooley, Member of Western Society of Engineers.

Introductory: The Proposed Waterway.

For those unfamiliar with the general project, a résumé of the essential features is thought advisable. For a more comprehensive presentation of the scheme, the reader is referred to a brief upon "The Lakes and Gulf Waterway," published by the Citizens' Association of Chicago, January, 1888; and also to "The Waterway between Lake Michigan and the Mississippi River, by way of the Illinois River," by Robt. E. McMath, Member of the Engineers' Club of St. Louis, published in the JOURNAL for August, 1888.*

In comparatively recent geological time, the three upper lakes—Superior, Huron and Michigan—discharged their waters across the Chicago divide and down the Illinois and Mississippi to the Gulf. Lake Erie was then a valley tributary to Lake Ontario, which, with Lake Champlain, fed the St. Lawrence. Across the old divide from lake level to lake level is but 30 miles, about one-half the distance being rock. This rock lies but 8 feet above low water in the lake and but 4 feet above high water, and alluvial deposits to a height of 12 feet above low water are of limited extent. The obstacle is far less than that overcome nearly seventy years ago in carrying the level of Lake Erie by the Erie Canal from Buffalo and the Tonawanda River across the mountain ridge to Lockport.

Around Chicago beach lines are well developed at about the right elevation to give to the old outlet the discharging capacity of the present Niagara. At 40 miles from the lake the valley is 77 feet below the lake, and in 100 miles the head of the alluvial valley is reached in a descent of 142 feet. The alluvial valley, with a wide and low flood plane, much cut up by swamp and lake, extends for 225 miles to the Mississippi, with a grade of only 26 feet. The evidence everywhere is significant of the ancient outlet, and it is marvelous that the erosive forces should have failed by so narrow a margin to maintain it, and in the epoch since to have completed the grade to Lake Michigan. Then would Michigan and Huron have been a hundred feet lower without material impairment of area, and the outflow would have given a continuous depth of not less than 30 feet to the Gulf of Mexico. How far can man realize the primitive conditions?

The arable area of North America is largely embraced in two continental valleys or basins, or virtually one trough, extending from the Gulf of Mexico by the lakes to the Gulf of St. Lawrence. The lowest line of this trough, its thalweg, is necessarily the feasible route for a continental waterway, and the summit is the Chicago divide, 200 feet lower than any other pass from the basin of the lakes to that of the Mississippi. Eastward, the descent is almost entirely in rockbound channels and by precipitous falls and rapids. Southward, it is on a grade through alluvial plains. The improvement eastward demands but a small volume of water, the levels maintained by dams and the descents overcome by short canals and locks; the improvement southward demands a large flow at seasons of low water to maintain a proper channel for navigation through the mobile alluvium. These considerations make evident the treatment required for the greatest waterway, and we can believe

* For copies of these papers address the Citizens' Association, Chicago.

that the largest useful depth is feasible and within the resources and wisdom of the nation. If so grand a purpose is within engineering resource, all the relations of a project which only approaches it in a minor and fractional degree can certainly be met, and it may well be so designed that in a progressive development from present needs the greater purpose can in some future be realized.

The Illinois & Michigan Canal, from Chicago to La Salle, 100 miles, was completed in 1848, and in 1871 the summit level was cut down so as to carry from 200 to 550 cubic feet per second by gravity, according to the stage of water in Lake Michigan. This reversed the current in the Chicago River, and conducted to the valley, 30 miles from Chicago, the major portion of the sewage of the city so far as it was undecomposed by the time the canal was reached. The nuisance in the valley was so great that in 1882 the city was compelled to erect pumps of 1,000 cubic feet capacity per second, and these have been operated to about 800 cubic feet during the past two years. The maximum capacity of the canal by pumping is about 1,500 cubic feet.

At the present writing the sewage of about 800,000 population and a host of waste-producing industries is nominally tributary to the canal, but no inconsiderable proportion is quite decomposed before the canal is reached, and all is more or less "oxidized," so that the condition of the canal by no means represents the pollution which would be occasioned by fresh sewage. The present contribution to the Illinois Valley is the cause of loud protests.

That some radical solution of the situation would be required has been recognized in some degree for ten years. In 1885 a committee of the Citizens' Association carefully reviewed all the feasible plans, and concluded that a ship canal carrying a large volume of water to the Illinois was altogether the least expensive, and at the same time covered the costly section of a deep waterway to the Mississippi. The volume, so far as then discussed, was assumed at 10,000 cubic feet per second.

During the following year, a drainage commission was organized and expended $65,000, but did not complete its work and make a final report. Its preliminary report of January, 1887, rejected all other solutions on account of cost, and recommended the ship channel with a minimum capacity of 10,000 cubic feet. As a channel of this capacity and not less than 160 feet wide and 22 feet deep, it was favorably reported by a joint committee of the General Assembly of Illinois in the spring of the same year.

The estimate at that time on the dilution required varied from 250 to 350 feet per second for each 100,000 of population. The recommendation was considered sufficient for 2,500,000 population, and was equivalent to 400 feet per second for each 100,000 people. This larger estimate was, however, based on the capacity required to keep the sewage from backing out into the lake when the channel was taxed by storm water from the tributary water-shed.

The observations since made indicate that the larger ratio of dilution may be required for a satisfactory sanitary condition, though the question has not been conclusively determined. Additional light will be thrown upon the matter by the observations now in progress by the

State Board of Health. The probable growth of population is, however, greater than hitherto estimated, and whatever ratio is finally fixed upon, 10,000 cubic feet per second will provide for a brief enough time in the future.

The present population of the metropolitan area, Chicago and immediate suburbs, is 1,025,000, a growth of 450,000 in the last eight years, and the probable population is 1,175,000 in 1890. The normal growth curve indicates a population of 3,000,000 in about twenty years, while the most pessimistic analysis cannot assign over thirty-three years. Considering the political agencies to be provided and the interests of the State and Nation, it will be not less than six to eight years before the work can be completed.

This volume of water will render the improvement of the Illinois a very simple matter. will give 7 feet without locks and dams in the alluvial section, a depth which can be increased to 14 feet by dredging. The government is now engaged in the consideration of a project for this depth of water on the basis of this contribution from Lake Michigan. It will also add not less than 1 foot to the depth for navigation from the mouth of the Illinois to Cairo and 6 inches below Cairo. The present project for the improvement of the Illinois is by locks and dams for a light draft steamboat navigation, and a limited proportion of the work to reach Lake Michigan has been done. The natural conservatism of the official mind is most difficult to change in favor of a bolder and more useful project from an unauthorized source.

The deep channel proposed is economical for carrying a large volume of water and for easy navigation, and will provide much needed harbor facilities for vessels of deep draft. It will also cover one-half the cost of carrying 20 feet of water 300 miles from Chicago, thus, for practical purposes, adding another lake to the great chain and extending a commerce, which has shown phenomenal growth in recent times, while marine interest elsewhere show decadence.

The following series of papers relate to the effect upon the lake level of abstracting 10,000 cubic feet per second through an artificial outlet. Other questions have been raised, as, for instance, the damage to result in the valley from the addition to present normal flow. This is not important, however, as under the most unfavorable assumptions the aggregate cannot exceed a small percentage of the proposed outlay. This matter has been considered and the objection is not now raised except to secure proper legislative provision.

No doubt, legislation expressing the will of the State of Illinois and providing the necessary political machinery to enable Chicago to undertake this work will be had during the session of the General Assembly of 1889.

"LEVELS OF THE LAKES, ETC."

By Geo. Y. Wisner, Member of the American Society of Civil Engineers.

The elevation of the lake surfaces for any given year is a function of the volume of rainfall on the drainage basin, the amount of evaporation and the outflow through the river system.

The rainfall and evaporation for Lakes Michigan and Huron each vary

from 20 inches to 30 inches per annum, but are seldom equal for the same year. Years of maximum rainfall are often those of minimum evaporation and vice versa.

For this reason the rainfall and water level curves are seldom symmetrical for any two consecutive years.

The clearing up of the dense forests which formerly surrounded the lakes has undoubtedly had a modifying influence on the fluctuations of the water surfaces. In cases of heavy freshets, the water finds its way into the main streams and thence into the lakes in a few days, where formerly it would have been held for weeks in the immense swamp reservoirs which existed throughout the surrounding forests. The ground being subjected to greater extremes of drought, the average evaporation is less and the volume of water that finds its way to the lakes is consequently greater than formerly.

These fluctuations of the lake surface have only a relative bearing on the question of effect of outflow on the lake levels, and need not be considered in this discussion.

The probable effect of withdrawing from Lake Michigan or from the St. Clair and Detroit rivers 10,000 cubic feet per second (the amount proposed for the discharge through the waterway) is not susceptible of an accurate determination from the data that can now be obtained ; yet it would seem that with the knowledge we have of the physical features of the river system a much closer approximation ought to be arrived at than the various estimates that have been made would indicate. As it may be several years before complete data for a full discussion of the flow of water through the river system is obtained, it is desirable that the change of lake levels, due to the withdrawal of a portion of the discharge to supply artificial outlets, should be determined as closely as possible from the knowledge now at our disposal.

The only determination that has been made of the discharge of the St. Clair River is that made by the U. S. Lake Survey during 1867, 1868 and 1869, which for the mean level of Lake Huron gives a discharge of about 225,000 cubic feet per second.

Mr. Chas. Crosman, in his recent "Chart of the Fluctuation of the Lake Surfaces," gives the mean discharge for the St. Clair River as 225,000 cubic feet per second, which is probably approximately correct.

The difference of the mean levels of the water surfaces of Lake Erie and Lake Huron is 8.4 feet distributed along the river system as follows:

Detroit River, 27 miles	3.0 feet
Lake St. Clair, 16 miles	0.0 feet
St. Clair River, 41 miles	5.4 feet

The greater portion of the fall in the Detroit River is in the lowe six miles, in the vicinity of the Lime Kiln crossing. The St. Clair River at the foot of Lake Huron is about one-half mile wide, and in a distance of 2,500 feet down stream narrows up to 750 feet in width, and for the distance of more than a mile flows with a mean velocity of about 7·5 feet per second, or 5 miles per hour. From the foot of these rapids to the head

of the delta, 12 miles above Lake St. Clair, the river has a large cross section, and flows with nearly a uniform velocity of 3.0 feet per second, or two miles per hour. From the above it is evident that most of the fall must occur at the rapids and in the delta above Lake St. Clair.

On page 607 of the Final Report of the U. S. Lake Survey, the slope of the river at St. Clair is given as 0.5 inch per mile. This, however, seems somewhat small, for by taking numerous cross-sections of the river between Port Huron and the head of the delta and applying Kutter's formula, a slope of 0.75 inch per mile is found necessary to give a discharge of 225,000 cubic feet per second. Applying the same formula for the cross-section at the rapids, a slope of 10 inches per mile is obtained for the same discharge. The fall at the rapids will be increased by the head required to produce the high velocity. The 5.4 feet fall of the St. Clair River must consequently be distributed somewhat as follows:

Lake Huron to foot of rapids, 1.5 miles, about.......	1.90 feet.
Foot of rapids to head of Delta, 28 miles, 0.75 inches per mile.........	1.75 "
Head of Delta to Lake St. Clair, 11¾ miles, 1.8 inches per mile.....	1.75 "

From a consideration of the above physical features of the St. Clair River, it is evident that a change of level of the water surface of Lake Huron would not materially affect the slope of the main river, but would have its principal effect on the slope of the rapids. This is well illustrated by the discharge observations made at St. Clair in 1867. The results for discharge on different dates have ranges of over twenty per cent. of total volume of discharge with scarcely any change of the gauge reading at the place of observation.

This change of velocity of current was undoubtedly due to fluctuation of the water surface of Lake Huron caused by winds and changes of barometric pressure. These fluctuations probably varied from 6 inches to 2 feet in amplitude, and yet the effect on the height of water at St. Clair was hardly noticeable. Taking the mean velocity of the current at the rapids as 7.5 feet per second and the slope at 10 inches per mile for a mean stage of water in Lake Huron, a change of 10,000 cubic feet per second in the volume of discharge would correspond to a change of 2.0 inches in the slope on the rapids, and the change in head due to velocity would be about 0.75 inch. As the water level below would be affected about 0.5 inch, the total effect of change of volume would be equivalent to a change of 3.25 inches in the lake level. As this difference would diminish rapidly for lower stages of water, it is probable that the low water level of the lake would never be affected to exceed two inches and a half by withdrawing 10,000 cubic feet per second from Lake Michigan for the proposed waterway. The lowest stage occurs in winter, when navigation is closed.

The area of the surfaces of Lakes Huron and Michigan is 46,250 square miles, as given by the latest determinations. Ten thousand cubic feet of water per second taken from Lake Michigan for waterway purposes would lower the surface of these two lakes 3 inches per year if considered independently of the natural outlet and without inflow or evaporation. The annual rise of the lake usually covers a period of about four months, and consequently the variation in the yearly fluctua-

tion of the lake surface due to withdrawing such a volume of water could not exceed one inch.

There are other physical features of the river system taken as a whole that have a modifying influence on the slope and velocity of the river. The water level of Lake St. Clair is to a great extent governed by the depth of water at the Lime Kiln crossing near the mouth of the Detroit River, and as a change of 10,000 cubic feet per second in the discharge of the river would produce but a very slight change in the water level at this point, the level of Lake St. Clair would remain practically unchanged, and consequently change of slope in the river due to change of level of Lake Huron would be distributed above this point.

When we consider that hourly fluctations of the lake surface of from 6 to 30 inches in amplitude are constantly taking place, it is evident that the withdrawal annually of a volume of water from Lake Michigan, equivalent to 3 inches in depth over the surfaces of the two lakes would not be appreciable in any ordinary set of gauge readings, and would certainly have but little effect on the depth of water in the connecting waterways.

Any investigation of this subject that may be made in the future should not only take into account the discharge of the St. Clair River at various stages of the lake level, but also the slope of the different sections of river for each stage. Self-registering gauges should be established at the foot of Lake Huron, at foot of rapids in head of river, at head of delta above Lake St. Clair, at the St. Clair flats canal and at the head of Lake Erie, and the zeros of all the gauges connected with lines of level.

DISCUSSION BY L. E. COOLEY, MEMBER OF THE WESTERN SOCIETY OF ENGINEERS.

Apart from any practical application, a comprehensive series of discharge measurements of the outflow of the lakes would be of great scientific interest. Such measurements could not be discussed except with the aid of some such determination of the slopes in the connecting rivers as suggested by Mr. Wisner. So far as the effect on the level of the lakes being a matter of practical moment, the subject may be dismissed.

When a waterway to carry 10,000 cubic feet was first proposed, some three years ago, naturally, the effect upon the lake levels was the first question to suggest itself. I then concluded that this would not exceed three to four inches and did not think it judicious to raise the question. It has been raised, however, and made much of by those opposed to the project, so it seems necessary to discuss it publicly.

In a recent pamphlet, "The Lakes and Gulf Waterway." I have considered the data briefly in a variety of ways, with the general conclusion that a change of one foot in level would be equivalent to a change of 30,000 to 40,000 cubic feet per second in the discharge of the St. Clair River. These deductions were made independent of any considerations introduced by changing slopes. I append this discussion as part of my remarks upon this subject.

Mr. Wisner's treatment of the problem indicates what may be called a throttle at Port Huron, a sort of reducing valve which regulates the

outflow without greatly altering the level in the river below. The observations taken seem to be in harmony with this view, an upward fluctuation in Lake Huron transmitting an increased velocity and discharge to the river below rather than variation in stage. If this be so, then any minor change in lake level, so far as the river system is concerned, is practically masked in the Port Huron rapids.

Suppose, as an extreme case, that in place of 10,000 cubic feet per second, it is desirable to withdraw a volume so large as to lower the level of the lakes by one foot, to what extent would the interests of navigation be injured ?

So far as Chicago and vicinity are concerned the benefit of a foot less height would be so great as compared to the small expense of deepening the harbors, that it would be looked upon as a blessing. The same would be true of Milwaukee and of every harbor of which I have knowledge about Lakes Michigan and Huron. The chief injury would be at the St. Clair flats and at the mouth of the Detroit River, and the cost at these places of another foot (it would probably be less) would be a comparatively moderate item. In fact, the cost of an additional foot for navigation at all the harbors of the two lakes and in their outlet would not be an amount of great moment. So we may conclude that the effect of withdrawing 10,000 cubic feet per second is not material.

In 1881, the Canadian Government was engaged in deepening the rapids of the St. Lawrence below Ogdensburg, from 10 to 16 feet, adding from 6 to 8 per cent. to the free channel. Much alarm was occasioned at Toronto and other Canadian ports through a fear that the level of Lake Ontario would be greatly lowered, and a similar interest was felt upon the American side. The question was finally referred to the Engineer Department through Senator Miller, of New York, and reported upon by General Comstock and Colonel MacFarland, the latter very elaborately. (See Report Chief Engineer, 1882.) The conclusion was that the effects would extend to no great distance, and that the level of Lake Ontario would not be impaired.

Similar cases are presented at the Lime Kiln crossing of the Detroit River, where the depth has been increased from 13 to 20 feet, and at the St. Clair flats, which have been deepened from 9½ to 16 feet, and where a farther deepening to 20 feet is now in progress; also, in the St. Mary's River, which had a depth originally of 9½ feet, since increased to 16 feet, and now in progress of deepening to 20 feet in a greatly shortened channel.

It is but fair to say that these cases are not strictly parallel to the one under discussion. Undoubtedly, an enlarged or less obstructed channel gives a freer discharge and affects the surface in the vicinity like an additional outlet. It distributes the local slope over a longer reach and thus increases the general velocity through the stream and its capacity for discharge. This of course will lower the surface of any lake from which the stream flows. The effect, however, diminishes up-stream from the locality, and at some distance, depending upon the size and character of the stream, may be considered as nothing; so the effect on a lake at a sufficient distance above is of no interest, except to a technical discussion in hydraulics.

These cases are cited to show how easy it is to raise needless alarm and to prejudice an important public enterprise. The data is certainly sufficient, from any scientific point of view, to satisfy the engineer that any effect upon the level of the lakes by the proposed waterway will never be appreciated by the navigator.

Gen. James H. Wilson, who prepared the project for a steamboat channel of seven feet depth from Lake Michigan to the Mississippi River in 1868, and which has been before Congress ever since, says in a letter published in "The Lakes and Gulf Waterway" brief, that "I am satisfied that such a discharge (10,000 cu. ft. per second, as now proposed) will not appreciably disturb the lake level." Mr. Robert E. McMath, in a paper printed in the August number of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, concludes "that the effect upon the lakes, that is, upon the depth at entrances to harbors and through the St. Clair channel, will be practically nothing." Mr. McMath was for twenty years upon the improvement of the Mississippi and Illinois rivers, and was General Wilson's principal assistant when he was in charge of the latter stream.

General Wilson, Mr. McMath and Mr. Wisner, from long and intimate familiarity with the conditions affected by the proposed water-way, should be well prepared to apply theoretical considerations. Every one who has considered the data seems to reach the same conclusion.

From my own point of view, however, I am so fully convinced of the good effects of 10,000 cubic feet per second added to the low-water volume of the Mississippi, that I believe that it will be only a few years after the construction of this waterway before we shall have to consider the effect of abstracting a volume three or four times as large. It may be said here, that it is quite within engineering resource to turn the entire discharge of the lakes in this direction, but no man would care to venture his reputation in discussing such a proposition at this time.

From "The Lakes and Gulf Waterway" brief:

[Further consideration, see "Data, etc.," at end of discussion.

APPENDIX NO. 8.—LAKE LEVEL EFFECTS.*

Lakes Michigan and Huron are so connected by the Straits of Mackinaw as practically to constitute one lake. Lake Superior is at a higher elevation, or is independent except so far as it is tributary to lakes Huron and Michigan. The waters of the three lakes drain through the straits called the St. Clair and Detroit rivers, some 85 miles long and with slight fall to Lake Erie. Whatever water is taken from Lake Michigan by the proposed Chicago outlet will diminish by that amount the quantity flowing out by the St. Clair River. What will be the effect on the normal elevation of the lakes?

The data for a complete discussion is insufficient. It is found principally in the reports of the Lake Survey (Chf. Engrs., 1868, 1869, 1870 and 1882). The following table is compiled from the latest and most authorative sources. The areas of basins and of lake surfaces are computed to the localities where discharge observations were made, viz., St. Marie, St. Clair, Lewiston and Ogdensburg, and include the intermediate lakes and rivers with their tributary water-sheds. The rainfall and

* This extract is corrected for the latest figures.

evaporation are computed on these areas for the year 1868.* The areas are given in square miles and the volumes in cubic feet per second.

Lake.	Elevation above mean tide.	Mean discharge	Total basin.	Lake surface.	1868.	
					Rainfall basin.	Evaporation lake.
Superior.........	601.8	86,000	82,800	31,200	171,430	27,690
Huron & Mich..	581.3	225,000	116,600	46,400	251,450	59,890
Erie..............	572.9	265,000	41,835	10,435	100,340	14,310
Ontario..........	246.6	300,000	30,790	7,280	73,840	9,590
Totals.......	....	....	272,025	95,315	597,060	111,480

The data indicate large variations in discharge from effects of winds and other causes, but give little clue as to the quantities at extreme low water and extreme high water. Extreme low water is probably 20 to 30 per cent. less, and extreme high water 20 to 30 per cent. more. These extremes are reached only in a long series of years, giving changes of level on the three lakes of 3 to 4½ feet. The mean annual fluctuation for 30 years has been for Superior 1.2 feet; Huron and Michigan, 1.34 feet; Erie, 1.55 feet: and Ontario, 2.07 feet; with probable variations in discharge of 10 to 15 per cent. from the annual mean.

For present purposes assume the discharge approximately as above, and the Chicago outlet opened for 10,000 feet per second. This would be less than 4½ per cent., but assume it at that amount, leaving 95½ per cent. to go down the St. Clair, after the level is adjusted to the new conditions; the ultimate lowerir g will be just the amount required to give the St. Clair River a capacity for 10,000 cubic feet less water.

It is a fundamental principle in hydraulics that in any stream the capacity for discharge will increase faster than the mean depth, or, for a given change in discharge, the change in mean depth will be less. If the stream is of uniform prism and unchanging grade, long established formulæ may be applied, viz.: that the new mean depth is the two-thirds power of the new discharge. The new discharge being 95½ per cent. gives the new mean depth at 97 per cent.—a diminution in mean depth of 3 per cent.

The channel is, however, irregular, of varying width and cross-section.

* Elevations are from final report of the U. S. Lake Survey (Primary Triangulation, etc.). Discharges, areas of basins and lake surfaces are compiled from tables by Mr. L. Y. Schermerhorn, republished by Mr. Chas. Crosman in his chart giving the fluctuations of the lakes for thirty years and much other useful information (Milwaukee, 1888). To these data are added 40 square miles water surface and 1,950 of basin for the St. Lawrence above Ogdensburg. Rainfall and evaporation are computed from data by D. Farrand Henry in reports of U. S. Lake survey. Various estimates have been made of the lake surfaces, but those computed by Mr. Schermerhorn from the final charts are doubtless as correct as present information permits. Mr. Wisner furnishes the following estimates by different authorities of the proper lake surfaces:

Lake.	Johnson's Encl.	Appleton's Encl.	Prof. Mitchell's Atlas of Mich.	L. Y. Schermerhorn.	U. S. Charts, lake survey.
Superior...........	31,400	32,000	32,000	31,200	31,200
Michigan..........	25,600	22,400	20,000	22,450	22,450
Huron.............	23,800	21,000	20,000	23,800	15,760
Erie...............	10,000	9,600	6,000	9,960	9,960
Ontario...........	7,300	6,300	....	7,240	7,240

Last column omits Georgian Bay from area of Lake Huron.

The experience on Western rivers indicates that the new mean depth will be a less power of the new discharge. If the one-half power be assumed, the diminution in mean depth will be 2¼ per cent. The St. Clair River is a stream of unusual regimen, and it is probable that the truth will be more nearly represented by the one-third power, giving for a diminution of 4½ per cent. in discharge, a diminution of 1½ per cent. in mean depth.

The mean depth in this case is that for an indeterminate section of the river below Lake Huron. What length is involved in the discussion will not now be considered. This mean depth is the average area of the cross-section of the stream divided by its average width, and for the St. Clair River, as judged from the published charts, will be nearly 25 feet. This will give a change (1½ per cent.) of 0.37 foot. or nearly 4½ inches.

Taking the mean depth for the whole stream as a uniform prism and without regard to ruling points gives the largest possible results.

To approach the matter comprehensively would require observations taken with the special view of ascertaining the discharge at different stages of the lake under varying conditions. So far as the observations can be used in a direct determination, they appear to indicate that the change of level for a difference of 10,000 cubic feet per second will be somewhere between 0.2 foot and 0.4 foot—say 1 foot for 30,000 to 40,000 cubic feet per second.

Some considerations may be presented, as showing how difficult it may be to detect or value any effects produced.

Considering the combined area of lakes Huron and Michigan as a reservoir (46,400 square miles), 1 foot of water will represent a discharge of 10,000 cubic feet per second for 4.10 years; or 2.93 inches that for one year. One foot of water on Lake Superior will represent this volume for 2.76 years: or 4.35 inches that for one year.

The extreme variation in the three lakes, for a series of years, is 3 to 4½ feet, and the ordinary annual variation from low to high water is 1 to 2 feet. There are also daily and periodic variations from wind, change of barometer and other causes, frequently of a foot or more. The surface of the lake is never constant, and can only be determined by observations continued over a period of time.

It is ascertained that changes in wind produce large variations in the discharge through the St. Clair River. The long series of meteorological observations at many stations about the lakes showed that there were great variations in rainfall, and that it was not uniformly distributed over the basin, being sometimes in excess in the upper lakes and deficient in the others, and sometimes the reverse.

These observations also show great variations from year to year in the evaporation.

The evaporation on lakes Huron and Michigan (see table) for the year 1868 would be about 17½ inches, and for 1867 (79,500 feet per second) would be some 23¼ inches, a difference for these two years alone of enough to supply the Chicago channel for two years. The difference on Lake Superior for these two years was nearly a year's supply.

On account of the many conditions involved, the great changes in lake level from complex causes, the variations in meteorological conditions—rainfall, winds, evaporation, vegetable growth, etc.—which it is impracticable to value closely, it is doubtful if long continued observations for lake elevation would detect a change and assign its amount. In other words, the abstraction of 10,000 cubic foot per second, so far as its effects are concerned, is not a matter of material moment, and might never be perceived.

An interesting question arises as to the amount that may be abstracted without raising broad questions of perhaps an international character, If the records for the last thirty years are studied, it will be found that Lake Erie begins to rise first in the spring, followed by lakes Michigan and Huron, and later by Lake Superior, which reaches high water in August or September. When 200,000 cubic foot per second passes the St. Clair River, the lake is still nearly one foot above low water. Certainly

any amount of water drawn from the lakes without impairing the natural elevations below this one foot would not be injurious to navigation, and would reduce high water and its destructive tendencies.

Suppose that works to regulate the outflow of Lake Superior be placed at the Sault Rapids, a matter of no great difficulty and of comparatively small cost. While supplying a certain minimum quantity to the St. Mary's River,* the high water can be retained until later in the season, or in place of coming in on top of the high water of lakes Huron and Michigan it may come in after it has run out. This may probably be done without injury to Lake Superior interests.

If proper observations for discharge at various stages of the lakes existed it would be possible, from the thirty years' records of stage on all the lakes, to deduce closely enough for all practicable purposes the regulative influence which could be attained by controlling the outflow of Lake Superior. It is very probable that such a study would show the feasibility of diverting not less than 30,000 cubic feet per second to the Mississippi, reducing the high water fluctuations in all the lakes below Superior, and without impairing—perhaps, on the contrary, improving—their levels for navigation. It is virtually to conserve the surplus above that required for a moderate stage of water. How far such regulation may be justified with a view to a large volume of water to the Mississippi is presented in the next appendix.

As an engineering question, it is quite possible to use the lakes as reservoirs to the highest degree desirable, or to even increase their discharge by diverting thereto streams which now flow to western rivers. This is not now a question for practical consideration.

Note.—There appears in the Detroit *Free Press* of January 8 and 11, two interesting communications in regard to the effect upon the level of Lake Superior of the proposed water-power canal at Sault Ste. Marie.

Mr. D. Farrand Henry states that the canal has been begun with a depth of 12 feet and a width of 100 feet, and that it is now proposed to make the width 250 feet, thus taking from the rapids about 10 per cent. of the outflow of Lake Superior. The effect of the smaller canal he regards as immaterial, but he states that the larger channel will lower the water above nearly 6 inches and diminish by that amount the depth for navigation in the U. S. Canal and the river above.

Gen. O. M. Poe, in charge of the government works from Lake Superior to Lake Erie, in his reply deprecates any alarm to the interests of navigation, and, admitting for the sake of argument the truth of Mr. Henry's conclusions, says: "A simple, easy and inexpensive way of remedying the evils which the writer of the article seems to fear, would be to reduce the cross-section of the river by building a spur-dam at the head of the rapids, thus intercepting an area equal to, or even considerably less than, the cross-section of the water-power canal;" and again, that it "surely would not require a construction of any great magnitude or cost; nor would it tax the ability and resources of the engineer to an overwhelming degree."

The application is obvious.

DISCUSSION BY LEWIS M. HAUPT, M. A. S. C. E., ENGINEERS' CLUB OF PHILADELPHIA, ETC.

However great the benefits to be derived from a public work may be, there will always be found an opposing element, because the proposed improvement may divert traffic from existing channels or means, and so apparently affect certain interests injuriously.

If there is a possible objection, either real or imaginary, which can be urged to prevent the consummation of the project, the parties interested in opposing will give expression to it, and the agitation concerning the injurious effect upon the level of Lake Michigan, which would result from withdrawing from it 10,000 cubic feet per second, appears to be such a *bête noir.*

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* The fall in the St. Mary's River from the rapids to Lake Huron is but two feet, and if it were desirable to, at times, entirely arrest the flow, it is practicable to conform the improvements at the Sault to this condition.

I have read the interesting and valuable papers on the subject contributed by Messrs. Cooley, Wisner and McMath, and have nothing to add to their exhaustive, theoretical demonstration, but there are a few practical considerations which do not appear to have been fully developed in this discussion which I think may have weight in the popular consideration of the subject. They refer more especially to the actual fluctuations of the lake's surface as affecting navigation. It has been shown that the amount of water required to maintain navigation in the Cooley channel (150 × 24 feet) might reduce the level of the lake three inches in one year or one inch in four months. That this would be inappreciable in its effect on navigation will be strikingly evident when we come to examine the physical changes of level from natural causes.

The extreme fluctuation in the level of Lake Michigan from 1836 to 1887 inclusive, as shown by the record furnished me through the courtesy of D. J. Whittemore, C. E., are found to be as great as 5.5 feet. The maximum elevation recorded was in June and July, 1838, when it was 4 feet above the city datum (Milwaukee), and the minimum was in February, 1847, when it stood at 1.5 below the zero. The annual fluctuations are not so great, being limited to about 2½ feet. The lowest water invariably occurs during the winter season, when there is no navigation, and the highest during June and July. In February of 1875 and 1880 the water level fell to the datum plane, but it is only the lowest water during the season of navigation that affects this question. The summer stage usually varies from 1 to 2½ feet above zero, but in the year 1872 it was unusually low and constant, and stood as follows: April, — 0.4; May, — 0.1; June, July and August, + 0.3; September, + 0.25; October, + 0.2.*

At no time since has the water been so low. It will be seen, therefore that the withdrawal of a few inches of water throughout the year would in no way affect the commercial interests of the lakes, and, as Mr. Wisner very justly concludes: "When we consider that the hourly fluctuations of the lake surface of from 6 to 30 inches in amplitude are constantly taking place, it is evident that withdrawing 3 inches in depth from Lakes Michigan and Huron would not be appreciable in any ordinary set of gauge readings, and would certainly have but little effect on the depth of water in the connecting waterways."

Before any injurious effect could be manifested in the St. Clair canal or river it would be necessary to reverse the direction of the currents in the straits of Mackinaw and Lake Michigan. I can imagine no public improvement which would be a better investment for the surplus or do more to promote the general interests of the whole country than the enlargement and completion of the Great Belt Waterway.

DISCUSSION BY CLEMENS HERSCHEL, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS, AND OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS:

If, in conformity to the invitation of the Secretary, I say anything upon the paper by Mr. Geo. Y. Wisner, entitled the "Effect

* The gauge records of fifteen years show the Chicago datum to be 0.691 foot below the Milwaukee datum. Chicago datum is low water summer of 1847, as adopted by the Illinois and Michigan Canal Commissioners.—EDITOR.

of the Proposed Lakes and Gulf Waterway upon the Level of the Great Lakes," it will only be to illustrate how such a subject impresses a hydraulic engineer, habitually working in quite another section of the United States, and dealing with very different bodies of water.

It seems to me that all considerations of the effect of the amount of annual rain-fall, of the varying distribution of that rain-fall throughout the year, of the annual and monthly evaporation, of the effects of the winds, tides and other disturbing causes, may, in the consideration of the precise subject above written, be left out of account.

These things we have always with us, and shall have in the future, not much less, nor much more, than we have had in the past.

Given a new outlet to Lake Michigan, carrying 10,000 cubic feet per second to the Mississippi River, or, we will say, 4.5 per cent. of the discharge of the outlet of Lakes Michigan and Huron combined, and naturally diverting just that much from the St. Clair River, it is evident that in only two ways can an equilibrium, or régime, be re-established.

1. The two lakes may be allowed to lower a certain small amount, until the discharge of the St. Clair River become 4.5 per cent. less than it was before, or

2. The area of cross-section of the St. Clair River at any ruling point or points may be reduced, artificially, until its discharge become 4.5 per cent. less, at times when the present lake levels obtain.

As regards the first proposition, I judge it to have been fully analyzed by Mr. McMath, p. 4 of his paper read before the Engineers' Club of St. Louis, May 30, 1888, and summed up when he says: "Lake Huron (and, of course, Lake Michigan) cannot possibly be lowered more than by the trifling quantity required to adjust the slope of the St. Clair River, now only one-half inch to the mile, to the volume (of its discharge) diminished by five per cent. * * * The conclusion is therefore safe, that the effect will not be noticeable, except as a result of a long series of observations, such as were required to establish the fact of a tide in the lakes."

As regards the second proposition, nature will to some extent work in the way indicated. For, given a reduction of 4.5 per cent. of the discharge of a stream having only one-half inch of slope to the mile, the tendency will be for that river by natural accretions to reduce its own cross-section, until the area of channel shall again be in conformity to the amount it is called upon to discharge.

Going to extremes of argument, I can conceive of a sufficient diversion of water from the St. Clair River and into new outlets, to cause the St. Clair Flats naturally and by accretion to become dry land, and a resultant material raising of the levels of Lakes Michigan and Huron to be brought about, by the method (paradoxical as it may seem) of diverting the waters of the two lakes to new outlets.

At all events, it seems to me, that should it be desired, religiously and with precision, to maintain the two lakes at their present mean level, a diminution of the discharge of the St. Clair River will offer the means for the accomplishment of such an end, and the ordinary processes of nature will co-operate in such an endeavor.

Four and one-half per cent. of the discharge of the St. Clair River is

less than 4 per cent. of the Niagara, and $3\frac{1}{3}$ per cent. of the St. Lawrence, and to maintain the levels of Lakes Erie and Ontario with the same precision, the discharge of the Niagara and of the St. Lawrence rivers would have to be diminished, in the same way or ways, to the extent of the small percentages above given.

DISCUSSION BY J. B. JOHNSON, MEMBER OF ENGINEERS' CLUB OF ST. LOUIS, MEMBER OF AMERICAN SOCIETY OF CIVIL ENGINEERS.

The effect on the level of Lakes Michigan and Huron of extracting 10,000 cubic feet per second at Chicago, depends wholly upon the outlet conditions at Port Huron. It so happens that these conditions are such as to concentrate the controlling functions within a mile and a half of the outlet of the lake. We find here a greatly reduced cross section, with a corresponding high velocity and steep slope, followed below with a large channel, low velocity and small slope. So emphatic is this natural development that the hydraulic problem reduces itself more nearly to the case of flow over a submerged weir than to the case of flow in an ordinay natural channel. The similarity to a submerged weir comes not only from the engorged condition of the channel here with reference to that below, but from its short length and from the still water of the lake just above it.

Evidently the true solution of the problem is to measure the discharge of the St. Clair River as near the head as practicable, and compare these discharges with simultaneous gauge readings at Lakeport, for instance, some 10 miles above the foot of the lake. There are permanent benches at this point, and it was here that the gauge was established which was used for determining the mean level of Lake Huron, and with which the line of precise levels from the sea was connected. Then by noting the variation in discharge for given changes in level of the lake it would immediately appear what change of lake level would correspond to a change of discharge of 10,000 cubic feet per second.

In the absence of such observations, however, it may be worth while to determine, as near as may be, its probable amount. In such a study I should prefer to approach the problem through a submerged weir formula rather than through a uniform flow formula.

Taking Mr. Wisner's figures as to volume, velocity and distance, but not as to slope, we have:

Discharge at Port Huron = 225,000 cubic feet per second.

Width of engorged section = 750 feet.

Velocity here = 7.5 feet per second.

Distance of this section from lake = 2,500 feet.

From the data given we find the mean depth must be 40 feet at the narrow section.

Probably the most acceptable submerged weir formula is that of Fteley & Stearns, which is

$$Q = c\ l\left(d + \frac{d^1}{2}\right)\sqrt{h} \tag{1}$$

where

Q = discharge in cubic feet per second.

c = numerical co-efficient = 3.3 for our case.

l = length of weir, or width of channel.
d = depth of water on weir above (in lake).
d^1 = depth of water on weir below (in lower river).
h = fall across weir = $d - d^1$
All dimensions being in feet.

For the case in hand, everything here is known except h, the fall from the lake level to the enlarged channel below. We can, therefore, compute this from the above equation. Doing this we find (calling $d^1 = 40$ feet)

$$h = 2.136 \text{ feet.}$$

Mr. Wisner has taken this at 1.9 feet. The submerged weir formula here used holds for a very short submerged weir (measured in the direction of flow), and for flow from nearly still water into nearly still water. Two of these conditions are not fulfilled in our case. The weir is long in the direction of flow, and the current below is comparatively strong. The long weir would require a greater fall than the formula would give, but the free escape of the water below would result in a less slope than shown by the formula. It is impossible to accurately evaluate these two conditions, but since they are in opposite directions, and are probably nearly equal, we will here assume that they balance, and suppose that the fall due to the submerged weir condition is, as given above, 2.136 feet.

To find the change in lake level, d, due to a change in volume of 10,000 cubic feet per second, we can substitute $d - d'$ for h in equation (1), and obtain

$$Q = c\, l \left(d + \frac{d'}{2}\right) \sqrt{d - d'} \tag{2}$$

Differentiating this equation for d and d' as independent variables we obtain:

$$\varDelta Q = c\, l \left[\frac{(3\, d - \frac{3}{2}\, d')\, \varDelta d - \frac{3}{2}\, d'\, \varDelta d'}{2\sqrt{d - d'}}\right]$$

$$\text{or } \varDelta d = \frac{4\sqrt{h}\, \varDelta Q + 3\, c\, l\, d'\, \varDelta d'}{3\, c\, l\,(2\, d - d')} \tag{3}$$

Where $\varDelta Q$, $\varDelta d$, and $\varDelta d'$ represent the changes in the discharge, lake level, and stream level below the weir section respectively.

If in this equation we let $h = 2.136$; $\varDelta Q = 10{,}000$ cubic feet; $c = 3.3$; $l = 750$ and $d' = 40$, then we have:

$$\varDelta d = \frac{11.8 + 60\, \varDelta d'}{66.4} \tag{4}$$

Now it is known that $\varDelta d'$ will be quite small for this is the change of level in the river below the engorged reach at Port Huron.

If $\varDelta d' = 0.0$, then $\varDelta d = 0.177$ foot = 2⅛ inches.
If $\varDelta d' = 0.05$ feet, then $\varDelta d = 0.223$ feet = 2⅝ inches.
If $\varDelta d' = 0.08$ foot, or 1 inch, then $\varDelta d = 0.25$ foot = 3 inches.

It is not probable that the river below the rapids at Port Huron will fall more than from ½ inch to 1 inch. In which case the lowering of the lake would be from 2½ to 3 inches.

DISCUSSION BY WM. PIERSON JUDSON, MEM. AM. SOC. C. E., MEMBER COMMITTEE ON TRANSPORTATION ROUTES, OSWEGO BOARD OF TRADE.

THE LOWER LAKES AND THE NIAGARA SHIP CANAL AS AFFECTED BY THE PROPOSED LAKE MICHIGAN AND MISSISSIPPI WATERWAY.

The proposed Lakes and Gulf Waterway, connecting Lake Michigan and the Mississippi River across the Chicago "divide," is a project whose execution would vastly affect lake commerce.

The papers by Mr. L. E. Cooley, by Mr. Robt. E. McMath, by Mr. Ossian Guthrie and by Mr. Geo. Y. Wisner, seem to leave nothing unsaid in favor of the project, and to remove any fear of an important lowering of the upper lakes, by the opening of the proposed waterway. Any perceptible lowering of lakes Erie and Ontario by it, may be put wholly out of the question.

As my interests for twenty years have been identified with the harbors on the lower lakes and on the River St. Lawrence, and also more recently with the proposed Niagara Ship Canal, I need therefore only consider the proposed Lakes and Gulf Waterway as it may affect these interests, or may divert commerce rather than water from the lower lakes and from their canals.

That a large amount of lake commerce would use the proposed waterway to the Gulf is beyond doubt, but this diversion from the present route would probably be offset by a general growth of business resulting from the increased facilities.

If the proposed 20-foot Niagara Canal to Lake Ontario, and the 9-foot enlargement of the Oswego and Erie canals to the Hudson are also made, this direct eastern route, with its cooler climate, need fear no competition from the longer Southern route to the Gulf. The main flow of commerce must be by the most direct line to New York, the focus of the country's business interests.

Even the present Erie Canal route from Buffalo could probably hold its share of the upper lake business; but still better could this eastern route do when it has the Niagara Canal to take the largest upper lake steamers to Oswego, where they could tranship their cargoes to barges, 146 miles nearer to New York than now at Buffalo.

From this point of view, I can only see that anything which will extend the channels and range of lake commerce must be for the ultimate good of the system as a whole; and that so far from the advocates of the Niagara Ship Canal opposing this proposed connection of the lakes with the Mississippi, they should rather further it in every way, regarding it as the completing link in the same chain, of which a deep-water United States canal around Niagara would form a part.

Each of these works would but make the other the more necessary.

It will be quite enough that the proposed Gulf waterway should pass the largest lake vessels without their loads, as suggested by Mr. McMath, thus permitting them to go down the Mississippi into Southern water for the winter. The increased range will be a great gain, which vessel owners will be quick to appreciate.

The military advantage of such an interior route to the sea would be important, and would go far to remedy the present lack of any effective defense of our Northern frontier, where our few forts are mere relics.

For the large 20-foot 3,000-ton steamers of the future lake commerce, it seems useless to consider deep canals to provide for carrying their full loads beyond the limits of actual lake navigation; or to attempt to take such steamers, loaded, nearer to the Gulf than Chicago, or nearer to New York than Oswego.

No large. seaworthy steamer. equipped to encounter lake gales, could afford to carry this costly and idle equipment through hundreds of miles of inland canals and rivers, whose scant depths would greatly impede their speed and management.

If the Erie Canal and the Hudson River had, to-day, 20 feet depth from Buffalo, or from Oswego, to New York, the lake steamers could not afford to use it; their freight would, in that case as now, be transshipped to barges which could handle it in the canal at less cost, and at less risk in transit.

The lower lake interests should, I think, join heartily with Chicago and the West in forwarding the proposed lake and gulf waterway; expecting an equal liberality from its friends toward the kindred Niagara Ship Canal project.

DISCUSSION BY WALTER P. RICE, MEMBER CIVIL ENGINEERS' CLUB OF CLEVELAND.

Press of business prevents my giving the thought or attention to the subject that I would like to. or that it merits, but I am willing to make the following fugitive comments.

Mr. George Y. Wisner. in his able paper on this subject, has correctly stated the relations between the elevation of the lake surfaces and the volume of rainfall on the drainage area, amount of evaporation and outflow of this great river system.

In close connection, although "relative," comes the consideration of the effect produced by the gradual extinction of the surrounding forests. This would undoubtedly lessen the actual amount of rainfall and increase the height of flood stages; in other words, increase the actual amount of the fluctuations—*i.e.*, the difference between the maximum and minimum stages. This effect is, however, relative and *within our control.*

Accepting the estimate of a withdrawal of 10,000 cubic feet per second. or at the rate of 2.9 inches per year. It becomes evident without going into the details of effects produced by readjustment of slope of the St. Clair River, which are insignificant, that the annual rise of the lakes from 12 inches to 16 inches in amount, the fluctuations of the past, marking from the highest annual rise to the lowest a difference of 6 feet 9 inches, and the hourly fluctuations due to winds, varying atmospheric pressures, etc., in amount often exceeding one foot (although these would only have local bearing), all these are so much greater in magnitude that no fears need be entertained about the withdrawal of 3 inches per year. Besides, the straits and channels connecting the system of great lakes have not the capacity to immediately discharge surplus waters, and if the lake level is lowered by the proposed canal, one of the first efforts of the flood stage would be to replace said loss—Nature striking her equilibrium. As confirmation I

quote the following from Elisée Reclus: "The gauges used at Geneva established the fact that the discharge of the Rhone at its issue from the lake is at its maximum 753 cubic yards; now, as the various affluents of the lake supply more than 1,400 cubic yards during their highest floods, it is evident that the Lake of Geneva acts as a complete regulator, retaining one-half of the inundation water which it subsequently empties down gradually when the tributaries retire to their usual level." Over, and above all this, if it were conceded that the effects would be detrimental. it would still be within the power and skill of the engineer to remedy. Finally, I am decidedly of the opinion that the effect on the levels of the lakes has no practical significance.

DISCUSSION BY D. FARRAND HENRY, MEMBER AMERICAN SOCIETY OF CIVIL ENGINEERS.*

The lakes are great reservoirs nearly level, but subject to many fluctuations, both periodic and secular. The difference in level between Detroit and Chicago, as shown by the Michigan Central Railroad survey, is 10½ feet, of which at least 8 feet is in the rivers between Port Huron and Detroit.

The discharge, as shown in my report on the outflow of the lakes, is about 48 per cent. of the rainfall on their surface and on the water-shed, and the fluctuation extending through several years is evidently dependent on the amount of rainfall, but often not noticeable until the year following, as shown in a profile of the curves of lake level and rainfall in one of my reports on the meteorology of the lakes.

Another change of level is due to atmospheric pressure. At Grand Haven and Milwaukee the difference of level due to this cause—after the wind effect was eliminated—was often over a foot, corresponding with the rise and fall of the barometer.

When the wind acts with the pressure the effect is much greater. Between Monroe and Erie on Lake Erie there was often a difference of 6 feet in the water level due to these causes acting simultaneously. Of course such changes of level cause currents in the lakes, and I have observed a current in Lake Superior in the open lake of at least three miles per hour. When stationed at St. Ignace I cut holes in the ice covering the Straits of Mackinac about a mile from shore and observed the currents. The direction at such times as I measured them was westward into Lake Michigan, and once was fully three miles an hour. The fishermen there in winter set their nets by cutting a line of holes in the ice, and passing the net from one to the other, and of course lift them in the same way. Once that winter when they tried to lift they found the current so strong that they could not draw in the net against it, and they had to wait till it ceased. Of course the true current through the Straits into Lake Huron must be very small, as they are over four miles wide and 250 feet deep.

There are other fluctuations whose cause is as yet obscure. At Sault Ste. Marie a change of level of over six feet has been observed, and once at Milwaukee a wave rushed up the river from the lake whose amplitude was estimated at over seven feet.

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* Mr. Henry was greatly pressed for time in preparing this matter, and trusted to his memory for his facts.

How, then, are the rivers (so-called) connecting the lakes affected by these changes? Where the fluctuations are regular and act through considerable time, they rise and fall the same as the lakes. Thus, during the season of navigation, the variation of level at the Flats is about one foot—nearly the same as it is in Lake Huron. But when the changes of level are irregular and abrupt their effect upon the rivers is limited—shown on the water-gauge, but not otherwise noticeable. In fact, the water-gauge at the flats was as good as a barometer, indicating the approach of storms, though the variations were small and required close reading. Probably the velocity of the current is also influenced by these changes, though not to the extent that Mr. Wisner states. He is mistaken in saying that the velocity observations at St. Clair only occupied one month; they extended over the whole working season of three years, and the large difference he notices was much modified by subsequent observations. The difference there shown is in part due to the fluctuation in the velocity of flowing water even under a constant head, which makes a large number of observations necessary to obtain a true mean velocity, but mainly to the fact that the observations he notes were made with the double float, which was found to be utterly unreliable, and was not used after the first season, being replaced by the telegraphic meter.

The area of the cross-section of the St. Clair, where the observations were made, was a little over 66,000 square feet, or about 1½ acres. At first thought it would seem as if a small fraction of an inch of rise or fall of the 50,000 square miles of Lakes Huron and Michigan ought to materially affect the depth or velocity of the water passing through this limited channel. But the whole chain of lakes must be considered as a great river widened in places, and subject to the same influences which cause certain fluctuations common to the whole system, while there are also fluctuations incident to the wide and deep lakes which do not much affect the connecting channels. Of course the actual observations are too few to fully establish these relations, but they all tend to show that the general rise and fall, due to extended causes, is nearly the same in amount, though differing somewhat in time over its whole extent. So that if the withdrawal of 10,000 cubic feet of water per second at the head of Lake Michigan would only lower the level of that lake and Lake Huron 2½ inches, as stated by Mr. Wisner, then the depth in the channel of the St. Clair and Detroit rivers would be only decreased by the same amount, or about one-fifth of the ordinary fluctuations during the season of navigation, or it might cause a slight decrease in the velocity of the current, amounting to about 0.2 of a foot per second at St. Clair: either of which would practically be inappreciable.

DISCUSSION BY BENEZETTE WILLIAMS, MEMBER WESTERN SOCIETY OF ENGINEERS.

By a careful reading of Mr. Wisner's paper and the discussions of it by Messrs. Cooley and Johnson, it becomes plain that, though an approximation may be made of the lowering which Lakes Huron and Michigan will sustain by the withdrawal of a given quantity of water through a new outlet, no exact determination is possible except by a series of

gaugings on the St. Clair River made with a view to such determination. It requires no measurements to establish the proposition that if the channel of the St. Clair River maintains its present proportions, that is, if there is no change in the regimen of the river, the lakes must suffer a decrease of mean elevation by the withdrawal, through another outlet, of any quantity of water, however small. Though the increment of decrease may be lost sight of in the hourly, daily and yearly fluctuations of the lakes, it will exist, nevertheless. It may be smaller owing to the rapids at the upper end of the river than it would be with a different sort of channel, but it cannot, by any method of sound reasoning, be wholly eliminated.

The proper way of determining the change of lake level is by discharge measurements of the St. Clair River extending over the whole range of lake fluctuations, and a comparison of discharges and elevations for different stages. By this means it would be shown, doubtless, that the withdrawal of 10,000 feet per second would affect the high stages of the lake much more than the low stages, but each and every stage would be affected in some degree.

These facts furnish opponents of the plan to drain Chicago by means of a channel through the divide between Lake Michigan and the Illinois River with standing ground from which to assail that measure.

As is usual in such cases, a germ of truth has been made to propagate error of far greater proportions.

In a paper read before the Illinois River Improvement Convention, held at Peoria, October 11 and 12, 1887, Major Thos. H. Handbury, the then Government Engineer Officer at Chicago, used the following language relative to the dangers which threaten the lakes from the proposed execution of the Chicago drainage plan :

"In treating of this question of drawing a large supply of water from Lake Michigan, there is one point of great importance that I do not find touched upon in any of the reports or discussions upon the subject: that is, the effect the withdrawal of so large a quantity of water from Lake Michigan, as is proposed by the Chicago Drainage Commission, is going to have upon the mean level of that lake.

"The discharge of the upper lakes through the St. Clair River has been found to be about 217,000 cubic feet per second. The mean level of Lakes Huron and Michigan is 581 feet above the sea; that of Lake Superior about 20 feet higher. The lower lakes receive their supply from this upper lake and the various streams that empty into them. The discharge is just equal to the supply and the lakes remain at their mean level of 581 feet.

"Now suppose we make another outlet in the bottom, or side, if you please, of this lower reservoir capable of taking off one-twentieth of this supply, which is the amount it is proposed to withdraw, what is going to happen in time to the mean level, to the depth of water in the various harbors, and to the channel of the St. Clair River, which the government is spending so much money to improve? This is a question upon which the people at the outer outlet of the lakes may wish to have something to say. It is, however, one of a purely engineering nature that can safely be left to a board of disinterested engineers to solve."

Subsequently at a meeting of the Executive Committee of the Peoria Convention held at the room of Judge Prendergast in the city of Chicago for the purpose of considering and formulating a bill to be laid before Congress to secure concerted action of the city of Chicago and the General Government in the improvement of the Illinois and Desplaines Rivers, Major Handbury stated that he estimated that the withdrawal of so large a quantity of water as that proposed by the Chicago Drainage Commission, viz.: 10,000 cubic feet per second, would lower the mean level of the lakes as much as one, to one and one-half feet.

It should be borne in mind in this connection that even if the mean level of the lakes should be lowered as much as a foot it should not prevent the carrying out of the important work proposed, nor would it be wholly injurious. At the worst it would only render it necessary to deepen the lake ports by that amount, while on the other hand many benefits would accrue, particularly to low lying cities like Chicago.

We can safely rest in the assurance, however, that a change in the level of the lake of so great a magnitude will not occur.

Though the data available is insufficient to settle definitely the amount which the lakes will be lowered by the withdrawal of a given quantity of water through a new outlet, it is possible to approximate the truth, and thereby prevent statements so seriously erroneous as Major Handbury's from obtaining lodgment in the public mind pending a proper investigation.

The only report made by the Drainage and Water Supply Commission of Chicago was a preliminary one, in which it was not possible to discuss this subject. It was, however, considered by the Commission, with the expectation that it would be treated of in the final report, which, unfortunately, was never made. The deficiency thus left has been ably supplied by Mr. Wisner's paper and the discussion which it has elicited.

The estimates of the lowering which the lakes will be likely to suffer by the withdrawal of 10,000 cubic feet per second through another outlet—which are as follows: Wisner, 2½ inches at low water, and 3¼ at high water; Cooley, 3½ to 5 inches; Johnson, 2½ to 3 inches—doubtless cover the range of the possible variation. At any rate, I believe they may be relied upon as the best obtainable results with the insufficient data to be had. But so long as the question rest upon uncertain or incomplete data we may not be surprised to experience renewed assaults from time to time upon the Chicago drainage plan, and we need not hope for protection from such attacks until the question is finally settled by a thorough hydrographic survey of the St. Clair River, conducted in such a manner as to definitely bring out the facts bearing upon the question.

DATA PERTAINING TO THE OUTFLOW OF THE LAKES.

Considerable research has been made for data pertaining to the problem of ascertaining the effect of diverting any volume of water from the natural outlets of the lakes. This matter is herewith submitted as briefly as possible, with such inferences as it seems to convey, and it may be useful pending any exhaustive determination of the question.

INTERMEDIATE CHANNELS.

The following notes pertain to outlets of the several lakes in their natural order :

St. Mary's River.—Outlet of Lake Superior ; mean discharge, 86,000 cubic feet per second.

The fall from Lake Superior to Lake Huron is 20.5 feet, of which about 18 feet is concentrated in the rapids at Sault Ste. Marie: two feet is distributed over the river below and one-half foot over the river above. So far as the level of Lake Superior is concerned, it is solely determined by the flow at the rapids.

Mr. D. Farrand Henry, who is very familiar with the rapids, furnishes the following memoranda: Length, 3,500 feet; fall, 17½ feet; width, about 2,300 feet; average velocity, 15 feet, when the river is discharging 92,000 cubic feet; mean depth, 2.7 feet, and section, 6,110 square feet. These figures are of course approximate. The international bridge is situated in the deeper water, just above the rapids or where the ice breaks off in winter. The water breaks over a massive sandstone ledge most of the way across.

This ledge constitutes the *virtual sill* or weir which controls the level of Lake Superior. If the rapids be assumed as uniform like a trough, the elevation of the lake above the *virtual sill* will be simply the mean depth in the trough plus the head due to the velocity. For a discharge of 86.000 feet, the mean depth would be 2.58 feet and the velocity 14.5 feet. The head due to the velocity would be 3.28 feet. The elevation of the lake above the sill would then be 5.86 feet, supposably at mean level. Whatever the actual conditions may be, this is doubtless an approximation to the truth.

The zero of any curve representing the relation of discharge to gauge reading should be at the *virtual sill*, and as the conditions approach those of a weir the equation will approach a weir formula. In other words, the discharge will vary with the 1½ power of the elevation above the sill, and, as a weir, the co-efficient will be 2.64.

If the above is assumed as correct, then for changes in level of Lake Superior near the mean level, the discharge will vary 2,250 cubic feet for each tenth of a foot. The mean annual fluctuation of 1.2 feet will represent a discharge varying from 73,000 to 100,000 feet.

St. Clair River.—Outlet of Lake Huron, and carrying the discharge of the three upper lakes ; mean discharge, 225,000 cubic feet per second.*

The fall from Lake Huron to Lake Erie is 8.4 feet, and the distance is 85 miles. The following data in regard to the stream from Lake Huron to Lake Erie is compiled from the published charts which are of too small scale for strict accuracy :

The St. Clair River is sufficiently uniform to permit a tabulation of its principal elements. Sections at regular intervals in each character-

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* Lake Michigan is tributary through the Straits of Mackinaw, which have a minimum cross-section of 1,558,000 square feet. See p. 607, Primary Triangulation, U. S. Lake Survey.

istic reach have been computed, and the results are tabulated as follows:

GRATIOT BAR TO MOUTH OF CANAL, 41 MILES.

Reach.	Distance, miles.	Average section, sq. ft.	Velocity, feet per sec.	Width.	Mean depth.	Net width	Net mean depth.	Remarks.
To Port Huron	2	35,000	6.43	1,300	27.0	900	35.9	See note below
To Vicksburg	6	51,000	4.40	2,100	24.3	1,700	28.0	
To Marine City	14	66,000	3.40	2,600	25.4	2,000	30.3	
To Head Passes	7	77,400	2.92	2,840	24.8	2,110	33.6	
In South Pass	6	36,000	......	1,600	22.5	1,050	30.0	One channel.
In South Pass	4¾	24,000	......	1,140	21.0	660	30.0	One channel.
In Canal	1¼	....	.....	300	16.0	300	16.0	

The minimum section at Port Huron is 31,000 square feet, with a width of 1,000 feet. This section is 660 feet wide inside the 18 feet contours, with a depth of 42 feet. The velocity would be 7.25 feet.

The river divides into several passes, forming a delta, and reaches Lake St. Clair through a number of mouths. The South Pass is used for navigation, but loses part of its water at the sixth mile, and only a small fraction passes through the canal across the bar. The bars at the several passes do not exceed 7 to 8 feet in mean depth. The mean depths given for the South Pass will apply approximately to the other passes. The combined area and width will exceed that of the river above. What is noted as "net width" and "net mean depth" in last two columns are these elements inside the 18 feet contours of depth. They signify the river as available for navigation.

Across Lake St. Clair to the head of the Detroit River is 17 miles, and the average depth is slightly in excess of 19 feet. The Detroit River is 27 miles long, and very irregular as to its dimensions. No attempt has been made to tabulate its elements.

In the first five miles are two islands and some middle ground. For eight miles, from the upper end of Detroit to Fighting Island, it is quite uniform, with an average section of 87,000 square feet, a width of 2,560 feet, and a mean depth of 34 feet. For the next nine miles to Stony Island, the river is subdivided by islands, and is very wide with doubtless a much larger section.

For the 20 miles from Lake St. Clair, or to within two miles of the Stony Island crossing, the net mean depth will run from 30 to 36 feet.

From about two miles above Stony Island, rock bottom of comparatively shallow depth extends for ten miles or more, reaching well out into Lake Erie. The minimum section on line of bridge at Stony Island is as follows:

	Width.	Section.	Mean depth.
Opposite dock	2,500	45,000	18
Stony Island bridge	1,000	7,000	7
American bridge	1,300	19,500	15
Total	4,800	71,500	15

At the Lime Kiln Crossing, immediately below Stony Island, the section is as follows:

	Width.	Section.	Mean depth.
Canadian Channel	8,300	76,000	9.5
American	2,700	35,000	13
Total	11,000	111,000	10

Five miles below Stony Island Crossing, at Bar Point, entrance to Lake Erie, the section is 20,000 feet wide, with an area of 296,000 square feet, and a mean depth of 14.8 feet. Over this reach and for three miles farther into Lake Erie, the channel of 18 feet depth is very limited.

Considering the channel from Lake Huron to Lake Erie as a whole, about two-thirds of the total fall of 8.4 feet appear to be concentrated in nearly equal proportions at three localities, viz: Port Huron Rapids, St. Clair delta and in the vicinity of the Lime Kiln Crossing, the balance being distributed over some 50 miles of river. It is evident that these ruling points largely determine the fluctuations in the river and in Lake Huron.

Independent of the general fluctuations due to volume of water which affect the lake and river system as a whole, the level of Lake St. Clair is probably determined in the largest degree by the Lime Kiln Crossing and the slope of river above, or is measurably independent of the fluctuations of Lake Erie. The following considerations bear upon this point.

Owing to its shallowness, meteorological causes produce marked fluctuations upon Lake Erie. The current at the Lime Kilns is sometimes increased to four or five miles per hour. The effect is seen in an estuary mouth of the Detroit River, practically unmodified by the littoral drift. Of course there is comparatively little detritus for a delta formation. The fact that there is a delta at the mouth of the St. Clair, formed by very slow accretion, presupposes freedom from rapid and frequent fluctuations, such as occur in Erie. The delta building material is supplied from erosion in the St. Clair River, still going on, the littoral drift under northerly winds down both shores of Lake Huron, which converge upon the head of the river, and the roily water from storm action.

The discussion would seem then to limit itself to the river from Huron to St. Clair. As the effect of the conditions in any given reach diminish up-stream, the lower reaches of the river will have less weight than those near the lake, and the St. Clair delta less than the Port Huron rapids. As these rapids present a section of radical resistance they are probably most largely determinative of the level of Lake Huron under the general conditions prevailing. (See discussion by Messrs. Wisner and Johnson.)

If the stream were of uniform prism and indefinite length, the general law of variation of volume with mean depth could be applied, the relative effect of any reach remote from the lake not entering. If the stream is of irregular section, but uniform in its general characteristics, the relation would involve higher powers. On the supposition that the river might be sufficiently long and characteristic to be determinative, the volume has been assumed to vary as the third power of the mean depth, the mean depth being taken at 25 feet or less. (See Appendix No. 8, Lake and Gulf Waterway.)

A method of discussion much applied to Western rivers is to determine the relation of volume to gauge height for any locality in question. The origin of all such curves is at that level at which flow would cease

if the stream be depleted—the crest of some bar below, or the surface of some body of water into which the stream debouches. In this case, it would be the level of Lake Erie, or it might be the level of Lake St. Clair, or the virtual crest of the delta bars.

If the level of Erie is assumed, the zero of the curve would be 8.4 feet below the head of the river. If the discharge increased uniformly from this level, then the increment for each foot would simply be $\frac{225,000}{8.4} = 25,600$ cubic feet. Such curves involve the second power of the gauge height, and frequently the third. The hydraulic conditions in this case imply a curve of high order. The increment would therefore be greater, and would probably exceed 4,000 for each tenth of a foot near mean level.

If the origin were taken at the level of Lake St. Clair, 5.4 below Huron, the increment would be correspondingly greater. If the level of the delta bars, 12 to 13 feet below Huron, be assumed, the increment would be less.

Niagara River.—Outlet of Lake Erie: mean discharge, 265,000 cubic feet per second.

The Niagara River, as it leaves Lake Erie, opposite Black Rock, is much contracted, and has a rapid fall and high velocity, more pronounced, but not unlike the St. Clair at Port Huron.

This contraction is about two miles long, the average width being 2,000 feet, the cross-section 35,000 square feet, the mean depth 17½ feet, and the velocity 7.6 feet, all as determined from the published charts. The fall in this section is 4 feet. The channel is comparatively large below, and is nearly equally divided by Grand Island from a point five miles from the lake to within three miles of the falls. The distance to the falls is 23 miles by the American channel and six miles less on the Canadian side. The fall from the lake to Tonawanda, some eleven miles, is approximately 7.5 feet, and to the foot of Grand Island 3.8 feet more, giving a grade to the river below Black Rock of about 0.4 feet per mile, and about 0.6 feet per mile to the Canadian channel. Immediately above the falls is a rapid descent of over 60 feet before the final plunge.

The conditions here are much simplified by the positive contraction at Black Rock and the free discharge below. It is apparent that the discharge curve must have its origin near the level indicated by the mean depth and that the variation of volume cannot be less than the 1½ power of the mean depth as in either the weir or mean depth formula, leaving out, of course, the variation in slope.

Small variations in gauge height will be practically the same in mean depth. In comparing discharge to gauge in cases like the present, it is usually found that the velocity varies uniformly while the area of section increases in a somewhat higher ratio—in other words, the discharge varies at not less than the second power of the hight above the origin.

If the second power be applied, the variation will be 3,000 cubic feet for a change of one-tenth of a foot at mean level.

The mean depth at the head of the rapids near the falls cannot exceed 7 to 8 feet. A change in level of Lake Erie would probably not affect the level at this point by over one-fourth. The increase of grade and the large channel below Black Rock are doubtless effective in producing a

larger increment. It is known that gales of wind upon Lake Erie produce very large variations at the falls.

St. Lawrence River.—Outlet of Lake Ontario; mean discharge, 300,000 cubic feet per second.

The following notes in regard to the St. Lawrence are from Maj. McFarland's report.*

At 45 miles from the lake and 5½ miles below Ogdensburg, the river descends the Galop rapids. The fall from the lake to the rapids is stated at about 4.5 feet, while the slope of the rapids is irregular and about 10 feet per mile. The section averages about 250,000 feet and the mean depth about 45 feet down to Ogdensburg. The section diminishes to 115,000 feet and the mean depth to 18 feet in the vicinity of the rapids. The section upon the upper bar is 36,000 feet with a mean depth of 11½ feet; and on the lower bar, one-half mile below, 25,000 feet with a mean depth of 9 feet.

The fall stated above the rapids is based on the average fall for the entire St. Lawrence and is doubtless in error. On the basis of the slopes found in the St. Clair River, it would be almost indeterminate. It is probably less than 0.5 feet, but will be assumed at that figure. The upper bar at the Galop would then be 12 feet below the level of Lake Ontario.

Considered as a weir, the increment would be about 4,000 cubic feet for each tenth near mean level. It is probably greater than this.

DISCHARGE MEASUREMENTS.

During 1867, 1868 and 1869, Mr. D. Farrand Henry, then an assistant upon the Lake Survey, was in charge of parties engaged in measuring the outflow of the several lakes. These measurements were apparently designed to ascertain the mean discharge during these years rather than to discover the variation with stage and cannot be applied with satisfactory results to the latter purpose.

Mr. Henry's experience with double floats led him to devise the telegraphic meter, which he used during the last two seasons. This instrument has since come into quite general use for velocity measurements. Both with the double floats and the meter, however, the observations were largely directed to ascertaining the distribution of velocities in the cross-section. This work was the occasion of a notable controversy with General Abbott (Humphreys & Abbott, Physics and Hydraulics of the Mississippi, etc.), and marks a renaissance in hydraulic investigation. Mr. Henry left the survey before the matter had been finally reduced for a permanent record. Since then great advances have been made in appliances, methods and skill, hydraulic investigations having been vastly multiplied. The accuracy of methods employed in all the earlier observations was greatly overrated, and it is only within a few years that they have been adequate to the studies now required in regard to the outflow of the lakes.

It is apparent that the volume of any stream flowing from any of the lakes will vary with the stage of water in the lake and that the change in volume may be compared to the change in level. If the observed volumes be platted to the gauge heights, a discharge curve may be constructed and its equation found. The origin or zero of such a

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*Rept. Chf. Engrs., U. S. A., 1882, p. 2,470 *et seq.* Effect upon level of Lake Ontario by improving Galop Rapids.

curve, as previously explained, will be at that level at which flow would cease, if the stream were depleted. These observations can be used for this purpose only to a very limited degree.

The observations rarely covered more than a fraction of the cross-section in any one day, and in computing the observations several days, and sometimes the season's work is reduced as a single measurement. Where the discharge is given for each day's work, it is ascertained by comparing the partial discharges with the mean for the season in the same portions of the section. The elevation of water is usually referred to a local gauge.

To utilize these data for the present purpose it is necessary to refer the discharge to the elevation of the lake from which the stream flows. For this the gauge records have not always been available, and it has been necessary to approximate the elevation from the published charts of fluctuations. There are large discrepancies in the individual measurements, due doubtless to change in flow distribution, sudden fluctuations and other causes, so they have been combined in groups for comparison with general lake elevation over a limited period. Such methods can have only the most general value.

The elevations given are referred to the high water of 1838, measuring downward.

St. Mary's River.—One mile below rapids. Mean level of Lake Superior, 3 feet below the assumed high water of 1838.

1867—(See Rept. Chf. Engr. 1868, p. 949 *et seq.*) Method of observation, by double floats.

From July 3 to August 5 inclusive, observations were made on 24 days and all reduced as a single measurement. There was little change in gauge height or volume.

Level of Lake Superior	2.20
Discharge per second	90,783 cubic feet.

The attempt to separate the data as presented into groups is unsatisfactory. Some of the comparisons indicate a volume of 18,000 to 20,000 for a change of one foot in level, while others are not significant. This is, however, close to the amount indicated by the hydraulic conditions at the rapids.

The level of the lake was some 0.8 feet above mean level. This would indicate the discharge of Lake Superior at about 75,000 cubic feet, or less than given by Mr. Schermerhorn.

No subsequent observations were made at Sault Ste. Marie.

St. Clair River.—St. Clair, 12 miles below Lake Huron. Mean level of Lake Huron, 2.82 feet below high water of 1838.

1867—(See Rpt. Chf. Engr., 1868, p. 949 *et seq.*)—Method of observation, by double floats.

From June 20 to July 19, inclusive, observations were made on 20 days, and all reduced as a single measurement.

Level of Lakes Huron and Michigan, 2.62 feet.

Discharge per second, 233,726 cubic feet.

1868—(See Chf. Engr., 1869, p. 562 *et seq.*)—Observations by meter.

From June 27 to September 17 observations were made on 44 days, only seven of which exceeded one-third the divisions in the cross-section. Reduced as one measurement, the result is as follows:

Level of Lakes Huron and Michigan, 3.42.

Discharge per second, 216,435 cubic feet.

1869—(See Chf. Engrs., 1870, p. 554 *et seq.*)—Observatio ns by meter.

From July 16 to September 3, observations were made on 26 days, usually over but one or two divisions of the cross-section. The mean for the series is as follows:

Level of Lakes Huron and Michigan, 2.82.

Discharge per second, 217,658 cubic feet.

The quantities have been compiled in the following groups:

Date.	No.	Local gauge.	Level of lake.	Discharges.	Remarks.
1867.					
June 20-30	8	2.08	2.73	232,732	By double floats.
July 1-11	6	2.05	2.64	234,500	
July 13-19	6	1.99	2.50	236,572	
1868.					
June 27-July 10	9	1.97	3.18	218,118	By meter.
July 16-28	9	1.96	3.22	221,135	
July 29-Aug. 13	9	2.03	3.36	216,088	
Aug. 14-26	8	2 11	3.57	215,791	
Sept. 1-17	9	2.19	3.70	210,226	
1869.					
July 16-27	9	1.02	2.92	205,986	By meter.
July 29-Aug. 20	9	0.94	2.77	220,665	
Aug. 23-Sept. 30	8	0.93	2.80	227,420	

From an inspection of the table it is apparent that it will not be judicious to compare the observations of different years. It is also apparent that the local gauge is not the same in different years.

With these cautions, a careful platting of discharge to gauge does not reveal definite conclusions. Several trends are suggested which apparently indicate results all the way from 16,000 to 50,000 cubic feet for a change of one foot in the level of Lake Huron. In the same manner a variation of 40,000 to 50,000 cubic feet is indicated for a change of one foot in the level of the St. Clair River. It is also apparent that the fluctuation in the river is less than in the lake.

The inference is similar to that derived from the hydraulic conditions. A platting of the quantities in detail does not change the indications.

The discharge at mean lake level is sufficiently indicated by the quantity given by Mr. Schermerhorn, viz., 225,000 cubic feet.

Niagara River.—Below Falls, in the vicinity of Lewiston; mean level of Lake Erie, 2.15 feet below high water of 1838.

1867—(See Rept. Chf. Engrs., 1868, p. 949 *et seq.*) Method of observation, by double floats.

From August 20 to September 25, inclusive, observations were made on 24 days, and all reduced as a single observation:

Level of Lake Erie at Buffalo, 2.36.

Discharge per second, 242,894 cubic feet.

Compiled in groups of six each, the results are as follows:

Date.	Buffalo gauge.	Discharge.	Remarks.
Aug. 20-27	2.18	252,451	Level at Lewiston
Sept. 2-11	2.30	250,542	simply indicates
Sept. 12-18	2.42	242,538	level of Lake.
Sept. 19-25	2.54	232,307	Ontario.

This table indicates a volume of 75,000 cubic feet for a change of one foot on the Buffalo Gauge or in the level of Lake Erie.

1868—(Chf. Engrs., 1869, p. 562 *et seq.*). Observations by meter.

From June 10–September 17 observations were made on sixty-five days, six of which covered half the stream. The data are reduced as two observations and as a whole, as follows:

	Buffalo gauge.	Discharge.
June 10-July 17	1.72	304,307
July 17-September 17	2.20	258,586
June 10—September 17	2.02	273,329

These quantities give 95,000 ft. for a change of one foot in level of Lake Erie.

The following detail table has been compiled from the daily discharges:

Date.	No.	Buffalo gauge.	Discharge.
June 12-30	11	1.68	293,563
July 1-17	14	1.76	290,506
July 22-August 15	15	2.03	258,052
Aug. 18-31	11	2.28	240,800
Sept. 1-17	14	2.34	239,700

This table indicates 87,500 cubic feet as the variation for one foot change of level.

The observations of this and the preceding year are in substantial accord, and indicates a much larger variation of discharge with gauge than that inferred from the hydraulic conditions.

1869—(Chf. Engrs., 1870, p. 554 *et seq*) Observations by meter.

From June 12–September 25 observations were made on fifty-seven days, of which eleven cover half the stream. The data are reduced as a single measurement:

Level of Lake Erie at Buffalo	1.75
Discharge per second	214,895 cubic feet

From the table of daily discharges the following is compiled:

Date.	No.	Buf. G.	Discharge.
June 10-24	10	1.97	219,810
June 25-July 9	10	1.68	214,438
July 10-27	10	1.48	217,987
July 28-Aug. 13	10	1.49	220,890
Aug. 14-27	10	1.90	192,012
Aug. 28-Sept. 25	7	2.06	212,354

No results are signified.

The volumes for this year are not in accord with those of the two preceding years. These indicate a discharge for mean lake about 5,000 less than heretofore adopted, or 260,000 in lieu of 265,000. It may stand at the latter figures until more conclusively determined.

St. Lawrence River.—At Ogdensburg, 40 miles below Lake Ontario. Mean level of Lake Ontario, 2.39 feet below the high water of 1838.

1867—(Rep. Chf. Engs., 1368, p. 949 *et seq.*)

Method of observation, by double floats.

From August 3 to September 17, observations were made on 19 days, and all reduced as a single measurement.

Level of Lake Ontario at Oswego, 1.45.

Discharge per second, 319,943 cubic feet.

Compiled in groups the results are as follows:

Date.	No.	Odgs. gauge.	Lake Ontario.	Discharge.
August 3-17	7	0.84	1.20	337,539
August 21—September 5	6	1.21	1.45	319,943
September 6-17	6	1.62	1.75	302,346

These quantities give 45,000 cubic feet for a change of one foot at Ogdensburg and 63,000 for a change of one foot in the level of Lake Ontario. The result is similar to that inferred from the hydraulic conditions.

None of the observations cover over one-half the cross-section.

1868—(Chf. Engrs., 1868, p. 562 *et seq.*) Observations by meter.

From June 15 to September 14, observations were made on 53 days, six of which covered one-half or more of the cross-section. The data are reduced as a single observation.

Level of Lake Ontario, 2.60.

Discharge per second, 272,095 cubic feet.

From the daily discharges, the following table is compiled :

Date.	No.	Ogdensburg gauge.	Oswego gauge.	Discharge.
June 15-30	10	1.94	2.32	268,660
July 1-15	11	2.00	2.37	268,262
July 20-31	10	2.27	2.59	270,790
August 3-14	7	2.29	2.60	275,204
August 18-31	8	2.49	2.75	265,220
September 3-14	7	2.60	2.85	267,880

These observations do not indicate any result, except that the fluuctuations are greater at Ogdensburg than at Oswego.

The observations of 1867 indicate 261,000 for the discharge of Lake Ontario at mean level, while those of 1868 indicate 284,000. The latter seems justified by the relative areas of the several basins.

No measurements were made in 1869.

GENERAL CONSIDERATIONS.

The chart of fluctuations for the past 28 years shows that both Lakes Erie and Ontario reach high water before Lakes Huron and Michigan. The high water of Lake Superior sometimes appear to prolong the high water in Huron and Michigan, or brings the culmination later than its normal time. The surfaces of Lakes Erie and Ontario are about 25 per cent. of their total basins and their tributaries are in nearly the same latitude, and also in the storm route, so that they get a concentrated inflow from melting snow or general precipitation. This gives a sharper annual fluctuation and a greater range than for the upper lakes, independent of outlet conditions. These effects may be imposed upon relatively large or small volumes from above, though this variation is limited by the capacity of the outlets and the reservoir action of the upper lakes.

Lakes Michigan and Huron, and Lake Superior also, are each about 40 per cent. of the total areas of their basins, and their tributaries are distributed over a considerable range of latitude, which gives a more gradual supply of snow-water. Both causes would diminish their fluctuations. The precipitation in the Superior basin is also less.

The hydraulic conditions at the several outlets are not the same, and if the lakes were subject to similar conditions in all other respects, the mean annual range, the mean discharge and the increment should have definite relations to each other. The relative value of the several increments should be indicated by the mean discharge divided by the mean range. Assuming 20,000 for the increment of flow due to one foot on Lake Superior, the St. Clair and Niagara rivers would each give 55,000, and the St. Lawrence 47,000. The conditions are not so radically dissimilar as to make this valueless as a general confirmation of previous inferences.

The writer has suggested a regulating dam at the Sault Ste. Marie, not for the purpose of meeting the effects of the abstraction of 10,000 cubic feet at the head of Lake Michigan, but to enable a far larger amount to be taken out for the purpose of improving the navigation of the Mississippi River by additions to its low-water volume, without impairing the level of the several lakes for navigation.

The present discussion makes it apparent that there are large variations in the discharge of the several outlets with variation in stage; the periods of high water are not identical, but those of low water are very nearly so. Any regulation should contemplate no lowering of the low-water plane; in fact, on the contrary, an improvement in steadiness near low water should be maintained.

In order to discuss this matter with a view to positive conclusions, the variation of discharge with gauge height at the several outlets should be carefully ascertained. The records of gauge height for the past thirty years will then enable the variation in discharge to be platted for that period. It is then simply a question of how far the discharge of Lake Superior may be applied so as to equalize the fluctuations on Huron and Michigan, and incidentally of Erie and Ontario. The chart of gauge heights for all the lakes under the new conditions could then be platted.

It is believed that by such regulation the surfaces of all the lakes below Superior could be permanently maintained at considerably over one foot above low water. If so, it would certainly be possible to abstract all the flow due to a variation of one foot without impairing navigation as existing under present conditions.

The effect upon Lake Superior would be to increase its range somewhat. The character of the shores and of the harbors upon this lake are such that no material interests would be seriously affected. The situation at the Sault is such that the cost of such regulation would be comparatively small, probably within one million dollars. The measure should raise no international question, for it would certainly be beneficial to all riparian owners on the other lakes.

There are many most interesting phenomena alluded to by Mr. Henry. The writer has made systematic observations for currents in the open lake, not only near shore, but across the lake from Chicago in 250 feet of water, and has never failed to find them, usually of less than one-half mile per hour. Periodic oscillations in 20-minute intervals are nearly always discernible on the automatic gauge and sometimes they assume a large amplitude, a range of two or three feet. There are many authenticated instances of very large fluctuations without adequate apparent cause.

Seven gauges set about Lake Michigan in 1886 and read at five-minute intervals seemed to show that the periodic oscillations were simply a swing of the water from shore to shore. What is more remarkable, one day's observations showed a general lowering over the whole of Lake Michigan of several inches, which could only have occurred by the transfer of the water to Lake Huron, through the Straits of Mackinaw. These were found to be of the requisite capacity, and the heavy currents found there at times are thus explained. A high barometer on Lake Michigan as compared to Lake Huron, sufficiently accounts for the phenomena. Generally, all these phenomena are referable to meteorological conditions.

The physics of the lakes have never been adequately studied, and it is a profoundedly interesting field for research. The writer had charge, under the Chicago Drainage Commission, of an extended series of observations of great value, but the work was never completed and the results digested. The matter is alluded to for the purpose of stimulating labor in an unworked field.

CHANGE OF GAUGE OF THE OHIO & MISSISSIPPI RAILWAY COMPANY'S TRACK.

By Isaac A. Smith, Member of the Engineers' Club of St. Louis.
[Read December 19, 1888.]

Early in the spring of 1871 the engineering department of the Ohio & Mississippi Railway Company was officially informed that the gauge of the track must be changed from six feet to four feet and nine inches, in the shortest time practicable. The magnitude of the undertaking may be better comprehended when it is understood that the length of the track from Cincinnati to East St. Louis is three hundred and forty miles, and the length of the branch track from North Vernon to Jeffersonville is fifty-two miles, making a total distance of three hundred and ninety-two miles. At the time this work was undertaken the entire track, including all bridges, trestles, water-stations and all other buildings and terminals, were under the direct control of the chief engineer of the company. The organization consisted of two division engineers, one superintendent of track, one superintendent of bridges and buildings, and a roadmaster for each fifty miles of road. The division engineers and superintendents of bridges and track ranked equally and reported to the chief engineer. The roadmasters reported for orders to the superintendent of track, and the superintendent of bridges had various sub-divisions of his work upon different parts of the road.

I desire to say in passing, by way of digression, that this arrangement, by which all of these features are kept under the control and management of a chief engineer, who fully and thoroughly understands his business, is to my mind a system best calculated to secure the greatest amount of service for the least expenditure of money. There are, however, comparatively speaking, but few engineers who understand enough about permanent way, terminals, water stations, bridges and trestles, and such other physical features as enter into the operation of a large railway, to occupy a position similar to the one I have described. This may be a result of there being but little demand for engineering service of this character, but it seems to me important that civil engineers should acquaint themselves with the requirements of constructed roads as far as possible, thus widening the range of their usefulness, and opening to them at the same time new and usually permanent fields of labor.

The chief engineer of the Ohio & Mississippi Railway at this time was Col. T. D. Lovett; Mr. R. L. Engle was division engineer of the Eastern Division, extending from Cincinnati to Mitchell, Indiana, and including the Jeffersonville branch, and the writer had charge of the Western Division from Mitchell, Indiana, to East St. Louis; Mr. E. S. Duval was superintendent of bridges of the entire road, and Mr. W. W. Jones trackmaster, each of whom reported for orders to the chief engineer. Preparations were at once set on foot to accomplish this work, and having no precedents from which to draw information, the engineers were thrown upon their inventive powers for plans. The chief engineer himself, while a man of great learning and engineering capacity, in the particular line of work over which he had control, had but little infor-

mation to give to his subordinates relating to an undertaking of this character. Being generally disposed to throw his subordinates upon their own resources, and thus strengthen and increase their efficiency, he was in this case compelled to do so. Upon consultation with the engineer of the Eastern Division it was deemed best as a first step to make a thorough examination and remeasurement of the track for the purpose of locating the tangent points of curves, valleys and summits of grades, the length of sidings, and all other matters of interest. On arriving at this conclusion we were met with the rather stubborn fact that by means of a chain this work would require too much time, and would not probably have been accurate in the end, and that some other method would have to be adopted. Consequently a device was made consisting of a wheel about three feet in diameter, whose axle was attached to an iron frame constructed with two arms, one on either side of the wheel, something like a tuning-fork, at the head or handle of which was a dial. The wheels moving the hands were geared to tenths, the large hand on the dial so adjusted that when it made a complete circuit of the dial the wheel had traveled 100 feet, the outer rim of the dial being graduated so that the hand would indicate each foot, or having 100 divisions, the fifth and tenth divisions being made prominent by being increased in length slightly, the tenth divisions being numbered from 10 to 100. The large dial was about 6 inches in diameter; five smaller dials were arranged upon the face of the large one, the hands of which would indicate hundredths, thousandths, ten thousandths, etc. For each complete circuit of the large hand the hand of the first small dial would move one point, and for each complete circuit of the small hand of the first dial the second small hand would move one point, etc. The large wheel was connected to the recording device by beveled gearing and a shaft. It was provided with a rubber belt to prevent slipping upon the rail. It was flanged like the driving wheel of a locomotive. The wheel was pushed along on the rail, and when one mile was reached the recording device set back to zero and another mile measured, and so on. Stakes for new mile-posts were numbered appropriately and put in at each mile. If an intermediate measurement was needed, the wheel was simply stopped right at the point and the index dial read, which gave the number of feet from the last mile. This measurement began at 160 feet east of the east line of Mill street, in Cincinnati, Ohio, and proceeded westwardly to the west end of the track at East St. Louis, Ill. The engineers took turns about in keeping the record and holding the wheel. The man operating the measuring machine sat upon a stool fastened to the front end of a hand-car, and held the dial end of the frame in his lap, while the wheel ran along upon the rail. The car was propelled in the usual way, but great care was taken to run it steadily. Sometimes twenty-one miles would be measured in a day, sometimes less, depending largely upon the kind of weather encountered. It required twenty-eight days to measure the road three hundred and ninety-two miles in length. We found all of the old mile-posts wrong; where the country was hilly he posts were too close together, and on level ground, especially over he prairies of Illinois, they were invariably too far apart. The main

line was found to be three hundred and thirty-eight and eight-tenths miles long instead of three hundred and forty. The branch developed no change. Every bridge, culvert, trestle, side track, the kinds and character of rails and joints, were measured and counted and carefully examined. The amount of fencing, the number of telegraph poles to the mile were carefully recorded. The quality and quantity of ballast was measured and recorded, and in fact every feature of detail was carefully examined, and, if necessary, measured. A special field book was provided which had the double page ruled with vertical columns, where every character of measurement and examination likely to be met with might be recorded. In the right-hand column of the left-hand page the measurement of the track was recorded; the different features, such as the grade, ties, ballast, culverts, cattle guards, bridges and trestles followed in columns to the right. The rails, ties, side tracks, curves to right or left, stations and section houses, telegraph poles and fencing were recorded in appropriate columns to the right or left going west as the case required. Each horizontal line of the record book represented one hundred feet, and a plus measurement was written between the lines in figures in a column set apart for that special feature to which the plus measurement referred. This arrangement was adopted to avoid field writing, which would have been very copious, consuming much time and space, and would have been, perhaps, difficult of intrepretation in the end. One engineer kept the record and the other run with the machine, alternating each day.

The next step in the progress of changing the gauge was changing the position of stringers on the bridges, trestles and cattle guards so as to bring them in the right position for the new gauge. This was done by moving the stringer one-half of the distance that the rail would have to be moved. This would leave the rail, while right for the old gauge, with sufficient support upon the ties, and would also support the rail when in its new position. The old gauge being six feet, the new four feet and nine inches, the difference was fifteen inches, and it was determined to move both rails inward seven and one-half inches, by which means the centre of the old track was preserved midway between the rails and also midway between the lines of the rights of way. Many stringers were condemned, and in such cases new ones were put in inside of the old ones and secured with packing blocks and bolts to the old ones. The new ones were, of course, adjusted for the new gauge. The ties of the track were thoroughly tamped to an even plane and were then adzed down so as to receive the rail when throw to the new gauge. This adzing was a very important and costly feature. The work had to be evenly done to a template that was constructed so as to fit on the rails, and a flat board was so fastened to the template that its under surface showed just where and how to adze the tie. After that was done, the inside row of spikes were driven in every tie for the new gauge. The template above referred to showed where they were to be driven. They were left standing up about one-fourth of an inch, so that the flange of the rail would slip under the heads of the spikes to its place. Then a chisel with a point like a spike was used to make a hole in the tie where the outside

spike would be driven. On all curves the outside rail was cut and put in the track just enough shorter than the old rail to allow for the new gauge, and the inside rail had its joints loosened so as to allow for the increased length.

It must be borne in mind that the character of the track was quite different from the tracks now in general use. The rails were mostly the old three and a half inch "pear" shape pattern, held together with bolts and long wooden joints, some of them five feet in length. Fortunately the bolt holes in the rails were elongated, and by loosening the nuts enough "expansion" could be secured to account for the increased length of the inside rail, but with the outside rail the case was different. Here a rail was cut the right length for the new track and put into place at suitable intervals. Upon the day of change no rails were cut. The frogs in use in the side track upon the main line were all of the old-fashioned spring frogs. They were usually one in eight, or No. 8 frog. Of course it was necessary to either change the head block or the frog in narrowing the gauge, and it was determined of the two evils to choose the least, therefore the head block, with the switch stand and all of its appointments, was left in its original position, and the distance from the head block to the point of the frog for the new gauge was carefully marked, the "lead" was carefully laid out with spikes in proper places for the flange, and rails were cut where necessary to substitute for those of the lead of the old gauge. By this arrangement the frog was changed to the new gauge almost as quickly as any other portion of the track. The side tracks were prepared for a change just as the main track was, but it was not intended to change them upon the day on which the main track was changed. Only enough side tracks were changed upon that day to be used for meeting points of the through passenger trains in service. This work of preparation required four months to complete it, and upon Sunday, the 23d day of July, 1871, the rails were thrown to their places and the gauge actually changed. The process by which this was done is as follows: The sections of track were divided into five miles each. About forty men were placed upon each section. They began their work at the east and west end of the sections and worked from and towards each other in gangs. Four men with claw bars led the gang of workmen and pulled out the inside spikes holding the rail in its position, these spikes having been previously loosened. Then six men, three on each side, followed, the first two throwing the rails over about one-half of the distance, the next two throw in about one-half the remaining distance, and the last two throwing the rail against the inside row of spikes. Following these men was one man on each side of the track with a hatchet in his hand, who picked up the spikes that had been drawn out and "tacked" them in outside of the rail at their proper places in the holes previously made. Following these came the men who swung the spike malls and drove the spikes to their places. A hand car followed with the materials required, furnishing new materials where necessary, and picking up and taking care of the old. This system was adopted upon the whole line of the road. The work began from four to five o'clock in the morning, and the time required to complete the change was from three to six hours. With some of the side

tracks it was necessary to use temporary cast frogs, but they were not generally used, and were discarded as soon after the gauge was changed as practicable. Two thousand seven hundred and twenty men were employed upon the whole line, 350 were obtained from roads centering in St. Louis 80 from Springfield, and 270 from Southern Illinois. They were paid 25 cents per hour for time actually employed upon the road.

New crossings made to standard gauge were provided for all railway crossings, and put in place by the crossing maker upon the day of change.

The total cost of the change of track was about $25,000. This does not include the reduction of rolling stock, or the purchase of new locomotives, but applies only to the track proper.

There was a large amount of work done by the other departments of the road, all looking to this event, such as putting standard gauge trucks under passenger and freight cars, reducing the size of boilers of engines, and putting them upon standard gauge trucks, arranging the terminals by putting in a third rail where needed, and many other matters of great importance to the success of the work as a whole, with which the writer had no official connection.

I would be glad to give the total cost of this work so far as it referred to the track, and the cost in detail of the various departments of labor; but having no official connection with the road now, and the time being so far in the past, it is impossible for me to do so.

Upon the day that the gauge was changed the passenger trains leaving East St. Louis in the evening, and also leaving Cincinnati in the evening, made their customary trips over the road without any delay. The day following the change the side tracks were all changed to the proper gauge, and on the second day following the business was resumed upon the line of the road as though no interruption had taken place; in fact, but very little interruption did take place. In those days Sunday was not used as a day for excursion trains, or a day to work off old delayed freight, as it is now, but was generally regarded as a sacred day and a holiday, and only sufficient trains ran on most roads to carry the mail, and these trains ran upon the day of change without any interruption.

Changing the locomotives was done by narrowing the fire-boxes 7½ inches on each side. The boilers averaged 40 inches in diameter, and the fire-box was reduced 15 inches in width.

The axles were shortened 7½ inches at each end, the machinery relocated, and the frame set in in the same proportion.

THE NECESSITY OF A DEFINITE AND DETERMINATE SYSTEM OF WEIGHTS AND MEASURES.

By Charles C. Breed, Member of the Western Society of Engineers.

[Read November 14, 1888.]

The measures of length, weight and capacity are of daily reference and use in individual and commercial transactions, and have been aptly ranked as necessities of life. There is no subject in which the general

business interest of the country, as well as progress in science in all of its departments, are more deeply involved. The subject having occupied the attention of the most abstruse thinkers and the ablest law-givers in all ages, necessitates an excuse being offered for choosing a subject whose intricacies suggest a modest distrust in the writer's ability to do it justice, and calls to mind that "Fools often rush in where angels fear to tread."

No one who has discussed the subject of our present system of weights and measures has considered the present arrangement an enduring one, on account of its being so deficient both in simplicity and in system. No cause has contributed more embarrassment to the facility of commercial exchange than our ambiguous system, with its many units of an indefinite character. Habit has indeed made us submissive to constant inconvenience, and while it is true that the United States was the first to move in the direction of a decimal system, the delay of our government, caused by the reluctance to make a violent change, and the desire to act in harmony with England, renders it possible that the United States will be among the last in the column of nations to take this step in the march of civilization.

The object of this paper is to show, as much as may be in the power of the writer, the many inconveniences involved in the want of uniformity between the different units of weight and measure, and the utter lack of connection, not only with each other, but with any natural or recognizable quantity.

Every system of measurement is founded on the possibility of transferring a fixed figure from one part of space to another with unchanged form, and by examination of the different methods of transfer we find that most of the quantities for which measurement is needed may be ultimately expressed by one of the following ways: Definite length, definite weight, definite capacity. Magnitudes possessing only one dimension present the theory of measurement in its simplest form, and to this class belongs the transfer of a fixed figure by measurement of length.

LINEAR MEASURE.

The different units used in the United States for the measure of length are derived directly from the English—strange to say the American people still cling to these old, arbitrary units established by another country.

The Mile.—The mile being the largest terrestrial measure of length in common use among the nations of the world, let us try and determine its origin. It is said to be derived from the Roman "Millaire," which consisted of one thousand paces of five Roman feet each. The pace was measured from the spot where one foot was set down to the spot where the same foot is again set down.

The modern mile in different countries exhibits a remarkable diversity not satisfactorily accounted for. During the thirty-fifth year of the reign of Queen Elizabeth an act was passed making the statute mile consist of 8 furlongs of 40 perches of 16½ feet each, or 1,760 yards of 3 feet each. The nautical or geographical mile bears the same relation to the earth's circumference at the equator in miles, as the minute or 1-60 of a degree does to the circle, and is therefore about 2,025 yards.

The Foot.—The foot is the most common unit of linear measure in use, and was evidently taken from the human foot; and as that varied in length in different countries, so did the measure. The established unit of measure of that name in this country was taken directly from the English standard, and is compared with the length of the pendulum to swing seconds in the City Hall in New York City, the foot being of the proportion as 12 is to 39.1012 inches.

We see by the foregoing that our system is no more determinate than was the standard established by Moses called the cubit (about 18 inches), taken from the average length of the fore arm, or the Roman digit, as the length of the finger, or the palm, or stride.

During the reign of Henry III., in the year 1266, the grain of wheat was taken as the standard of both weight and linear measure. Afterward, in 1324, during the reign of Edward II., the grains of barley were substituted for the wheat, hence it was declared that 3 barley corns *round and dry* shall make an inch, and 12 inches to the foot.

To show you some of the perplexities and embarrassments involved in our customary linear tables, I wish to cite the following:

In the government standards the yard is divided into tenths and hundredths. Engineers use neither the yard nor the inch, but divide the foot decimally into tenths, hundredths and thousandths. Mariners use the cables-length, consisting of 120 fathoms of 6 feet each. Land surveyors use the Gunter's chain, consisting of 66 feet, divided into 4 rods of 16½ feet, each rod consisting of 25 parts, called links; thus dividing the chain into 100 links of 7.92 inches, making it easier to measure land, as each square chain contains 16 square rods, and the acre consists of 10 square chains. Architects and mechanics reckon by the foot and inch, with the latter subdivided into halves, quarters, eighths and sixteenths. Dry goods are measured by the yard, with the subdivisions of half, quarter and eighth. Pendulum rods of clocks are measured by the "line," or one-twelfth of an inch, and the "point," or one-seventy-second of an inch. Horses are measured by the hand of 4 inches. Our linear system, now in actual use in tabular form, ascends from the barley corn to the league by factors of 3, 12, 3, 5½, 40, 8, 3.

WEIGHT.

In making the transfer of a fixed figure by measurement of weight we are forced by the custom of our country to use one of three systems of units, depending upon the substance to be measured.

Troy.—The standard weight for coinage purposes is the troy pound, derived also from the arbitrary English standard. It is subdivided into either 12 ounces, 240 pennyweights, or 5,760 grains.

Apothecary's.—The apothecary's table uses the troy pound as its standard, with the same number of grains, but is differently divided—consisting of 12 ounces, of 8 drachms, of 3 scruples of 20 grains each, and is used, as its name plainly shows, for measuring medicine.

Avoirdupois.—The avoirdupois table of weights, used more commonly than either of the other two, has a standard pound consisting of 7,000 grains, and is divided into 16 ounces of 437.5 grains, or 256 drachms of 27.344 grains. The ounce is sometimes divided into halves and quarters,

probably for the purpose of lessening the confusion occasioned by the fractional number of grains contained.

Quarter.—A weight called a "quarter," consisting of either 25 or 28 pounds, is also used; and a hundred-weight of four quarters enjoys the indefinite meaning of either 100 or 112 pounds—and as twenty hundred-weight constitute a ton, making the net ton equal 2,000 pounds, and the gross ton 2,240 pounds, according to the substance to be sold and the party selling.

Coal is sometimes bought by the gross weight and sold by the net ton. Pig iron generally has $\frac{1}{80}$ added for tare, thus making a pig iron ton of 2,268 pounds. In our three tables for weighing the only unit common to all is the grain. The avoirdupois pound is heavier than the troy pound, while the avoirdupois ounce is lighter than the troy ounce, the avoirdupois pound equaling 1.215 troy pounds, while the avoirdupois ounce only equals the .911 of a troy ounce. The apothecary's drachm is equal to 2.194 avoirdupois drachms. The avoirdupois pound contains 256 drachms, while the apothecary pound only contains 96. In the three tables of weight we ascend from the grain with the following factors, respectively: Avoirdupois, $27\frac{11}{32}$, 16, 16, 25, 4, 20; troy, 24, 20, 12; apothecary's, 20, 3, 8, 12.

CAPACITY.

In the measure of solids the extension of the linear measure to the third power is indulged in, and tables expressing cubical contents are used, possessing all the perplexities, only in a more aggravated form, shown by our table of linear measure. Some of the oddities are as follows:

In olden times a rod or perch representing $16\frac{1}{2}$ feet in linear measure was used quite extensively, and amounted almost to a standard; brick walls, and perhaps a great many cellar walls, were 18 inches thick; they were measured and paid for by the superficial perch of wall, which at 18 inches thick made $24\frac{3}{4}$ feet, cubic measure; this gave rise to $24\frac{3}{4}$ cubic feet being called a perch—then, to discard fractions, it was taken at 25 cubic feet, and it is within the knowledge of the writer of its being reckoned as 22 cubic feet (this is superficial perch times 16 inches), $24\frac{3}{4}$ cubic feet, 25 cubic feet, and even 27 cubic feet. This same measure is carried out in the use of the cord. A cord of wood, consisting of 128 cubic feet, was supposed to be piled 8 feet long by 4 feet high and 4 feet wide, and the custom arose of calling 1 foot in length times the end area of 16 square feet a cord foot, and 8 cord feet to the cord. In measuring round and hewn timber 40 and 50 cubic feet are respectively used as a ton, but for shipping purposes a ton of 42 cubic feet is used. In dressed lumber, everything depending upon the thickness of the boards, the superficial square foot of boards 1 inch in thickness is called a foot, "board measure."

Dry Measure.—In the measurement of capacity we have in addition to, and determinate from, the foregoing cubic measure, three units—all adopted from the English, differing in use entirely according to the substance measured. For measuring fruit, grain, salt and vegetables, the bushel, consisting of 2,150.42 cubic inches, is the unit of what is called the "Dry Measure." It is subdivided into the peck of 537.6 cubic inches, the

dry gallon of 268.8 cubic inches, the quart of 67.20 cubic inches, and the half quart or pint.

To make this unit determinate, the United States has made several efforts: one by saying it was equal to 77.627413 pounds of distilled water of the temperature of 39.8 degrees Fahrenheit with the mercury in the barometer at 30 inches. This bushel is identical with the old Winchester bushel that was introduced into England by Henry VII., sometimes called the "Solomon of England," and continued as the standard from 1490 to 1826. In that year England adopted the Imperial bushel of 2,218.192 cubic inches, which is equal to 80 pounds of distilled water, at the normal temperature of 62 degrees Fahrenheit, with the barometer standing at 30 inches. This was certainly a step in the direction of making their measure determinate. The Imperial is equal to 1.03152 Winchester bushels. The United States' standard is still the Winchester, with the exception of New York State, where they have made a bushel equal to 2,211.84 cubic inches—consequently their peck, gallon and quart dry measure are different from all others of the same name, being:

Peck, one-fourth of bushel, or 552.96 cubic inches; gallon, one-half of peck, or 276.48 cubic inches; quart, one-fourth of gallon, or 69.12 cubic inches.

The Winchester bushel being used to measure fruits and vegetables leaving large interstices in the contents, it is expected to heap the bushel for fair dealing, and were you to use a shallow and wide measure the difference would be apparent; so to overcome this the law has fixed the shape and dimensions, which are as follows:

Internal diameter, 18½ inches; external, 19½ inches; depth, 8 inches; and with articles requiring to be heaped, the cone shall be six inches high, thus making the heaped bushel 1¼ times the struck bushel, or 2,688 cubic inches, and adding another unnatural unit to the already too lengthy list.

Our dry gallon is one-eighth of the standard bushel, or 268.8 cubic inches, and by a happy coincidence one-tenth of the heaped bushel. The chaldron consists of 36 bushels. The bushel, although primarily intended to have but one value, has undergone a variety of changes. In nearly every State and in the customs tariff of the General Government the term is applied as a unit of weight, the law fixing the number of pounds to the bushel according to the substance weighed. The bushel consequently has, according to weight, 130 different sizes in this country, in addition to all of them being of a different size to the English bushel, to which country most of our surplus product is shipped in quantities measured by the bushel.

The disadvantage of so common a unit as the bushel, meaning one thing in one State and another in another, is easily seen. As an instance, it may be noticed that 1,000 bushels of barley bought in the State of Kansas at 48 pounds to the bushel, would become 1,500 bushels in New Orleans, where a contract for delivery would, in the absence of an agreement to the contrary, be satisfied at the rate of 32 pounds to the bushel. In the case of rye 1,000 bushels would, by the same transfer, become 1,750 bushels. Many States fix a ton of coal at 2,000 pounds, or 25 bushels of

80 pounds each, but the following weights have been used: 72, 74, 76, 78 and 80 pounds. Thus we see that even the most common products of the earth have no uniform standard of measurement.

Liquid Measure.—The gallon is and has been the standard measure for liquids from the earliest times, and consequently has undergone many changes.

In the time of Henry III. it was enacted, in an endeavor to make a measure of weight also a measure of capacity, that a gallon should be 8 pounds of 12 ounces, each ounce to be reckoned as 640 grains of dry wheat taken from the middle of the head. There are at the present time other gallons of the following dimensions: 277.274 cubic inches, 268.8 cubic inches, 282 and 231 cubic inches.

The first is the Imperial gallon of England, and is ⅛ of the Imperial bushel. It is therefore equal to ten pounds of distilled water at normal temperature and maximum density, and is used for both dry and liquid measures with the exception of ale or beer, when their particularly arbitrary gallon of 282 cubic inches is used.

The standard gallon of the United States is the old English wine gallon of 231 cubic inches, and was in use over there from 1650 until replaced by the Imperial gallon. We evidently think it good enough for us, as it is made determinate by comparison with 8.3389 pounds of distilled water at maximum density, with barometer at 30 inches.

New York State has adopted a liquid gallon of 221.184 cubic inches, thus making it equal to one-tenth of its bushel, but this apparently sensible standard is offset by having a dry gallon of one-eighth bushel. The gallon of milk in Vermont and Massachusetts is the wine measure of 231 cubic inches, while in New Hampshire it is the beer gallon of 282 cubic inches. None of the units of the liquid measure are identical with the units of any other measure. The Imperial gallon of England differs in size from any gallon used in this country. To add to this confusion there is in different parts of the United States a barrel of 31½ gallons, one for beer of 32, one of 36, and another for lamp oil of 43 gallons; the barrel for corn of 5 bushels, for fish of 220 pounds, for flour of 196 pounds, and for lime of 320 pounds, besides a tierce of 42 gallons, a hogshead of 54 gallons, a puncheon of 72 gallons, a pipe of 8 barrels, a tun of two pipes, and a butt of 108 gallons.

Care has been taken to eliminate all obsolete examples. The gallon has three distinct values, as have both the quart and the pint. Even in local transactions one meets with the troy and avoirdupois pound, the long, short and shipping ton, wine, beer and dry gallons, and with barrels of undefined sizes, making in all an aggregate of appalling confusion.

METRIC SYSTEM.

Excepting the inconvenient size of its fundamental unit, the metric system comes nearer to fulfilling our requirements than any, from the fact that it has only one unit of measure for weight and one for capacity, both bearing a simple relation to each other, and in fact both depending on the unit of linear measurement for existence.

It might be well to give the origin of this interesting system. On the 8th of May, 1790, proposals were made by the French Government to

the British for a meeting of an equal number of members of the Academy of Sciences and the Royal Academy of London, to determine the length of the simple pendulum vibrating seconds on the 45th degree of latitude at the level of the sea, with the view of making that the unit of measure; but Great Britain did not give this proposal favorable reception, and the idea, as far as being of international benefit, was lost. The French Government, impatient to effect reform, obtained the appointment by the Academy of Sciences of a commission composed of Borda, La Grange, Laplace, Monge and Cordocet, to choose, from the following sources, the one best suited for the purpose:

(1) The length of the simple pendulum.

(2) The fourth part of the equator.

(3) The fourth part of the polar circumference on the meridian passing through Paris.

They decided in favor of the last, resolving that the one ten-millionth part of the quadrant of the meridian (or from the equator to the pole), measured as along the surface of still water, should be the basis, and to be called the "metre," which by comparison is equal to 39.3707904 inches.

The friends of the metric system, while not without enthusiasm, have remained content with the law making it permissible for those to use it who found it adapted to their use, feeling that the many advantages it possessed would finally win its case through concerted private action without the aid of Federal legislation; but we have waited ninety years for the metric system to establish itself; and now there is a doubt raised as to whether the metre is really as it purports to be, one ten-millionth part of the quadrant of a terrestrial meridian, the accuracy depending entirely upon the true figure of the earth, as to whether it is a regular spheroid with an ellipticity of $\frac{1}{309}$, or an ellipsoid of three unequal axes.

Whether the metric system has employed an imperfect fundamental unit or not we must confess that on account of the metre not being commensurate with the inch, foot or yard, all reductions made would be only approximate; nor is it so convenient in absolute size, or so well suited to the conditions of ordinary transactions as some of the units now in use among us.

Our system of units as now used in the one branch of land surveying with the millions of acres already recorded, presents one of the most effective examples of the inapplicability of the metric system to our country. The legal township of the United States land survey is approximately a rectangular tract with sides of six statute miles. This body of land is divided into 36 sections with sides of 80 chains, each regular section embracing as nearly as can be, a square of 640 acres. In setting off the aforementioned tracts by the metric system, the sides of the township—6 miles—would measure 9 kilometres, 6 hectometres, 5 decametres, 6.083 metres. The sides of the section—80 chains—would measure 1 kilometre, 6 hectometres, 9.347 metres. The contents of a section, now briefly expressed "640 acres" would be 258 hectares, 99 ares, 98.41 centares. The contents of the convenient and briefly expressed quarter question of 160 acres expressed in terms of the metric system would be 64 hectares, 74 ares, 99.6 centares.

We cannot longer treat with indifference the numerous appeals that are being made from time to time by the scientific and business men of the country, urging the adoption of some improvement upon our present absurd system. In the acquisition of our present system of tables a great portion of time is absorbed which could be better applied to other studies. The arithmetical rules actually required are seriously multiplied, to the extent of embarrassing mathematical calculations, clogging the accounts of trade and increasing the labor in our schools of both teacher and pupil. In the decimal system we ascend and descend in all cases by the common factor of ten (10), thus placing the system for all purposes of calculation upon the basis of simple numbers.

To a full appreciation of the advantages of the decimal system the people of the United States may be considered committed by the adoption of this system in their currency, which for convenience apparently leaves nothing to be desired. The system approaches ideal perfection of uniformity and easy determination, and the time and labor saved by it in computations and accounts cannot but be a powerful argument in its favor; for with the decimal system all ordinary transactions of popular trade can be computed by any person familiar with the simple relations of numbers. Even in England the merchants count their interests, discounts and dividends in cents and dollars. Slowly but surely all standards of measure are being divided into tenths and hundredths, and whether we will or not it will eventually prevail, to the displacement of all other systems.

Some of the opponents of the metric system are so bitterly prejudiced, not only against the fundamental unit, but the decimal system involved as well, that they claim that no system will ever obtain that eliminates binary principles, for the reason that the natural inclination of the mind is to divide into halves and quarters. We can only say that we are fervent in our hope that they do not blindly follow this method of reasoning, or rather lack of reasoning, at all times, for the writer has heard it whispered that the natural inclination of the mind is to sin.

Our own system of weights and measures can be simplified and a less number of units employed ; and with every change made in the direction of a decimal scale it would certainly be far superior to the present. We see and approve of better things, although we are continually taking footsteps backward by persisting in following the worst.

The units of standard weight and measure should, for purposes of easy determination, be derived from some constant quantity in nature.

It is not difficult to extend our observations and perceive that if one system be advisable for one country, a universal cosmopolitan system would be no less advantageous for the whole world. The general adoption throughout the world of one common system would effectually remedy the evil arising from the inconvenience and confusion existing in both our domestic and foreign transactions.

It is essential that the unit of measure bear some simple relation to the earth's circumference, otherwise the operation of the surveyor will not accord with the geographer.

It would seem with these requisites making their importance apparent, that the source from which our cosmopolitan system will spring is in a

measure restricted. The system will consist of a single unit for each measure, bearing a simple relation to each other, and will have uniform multiples and subdivisions for all purposes of measurement. Until this system is universally adopted we may lose patience in believing that Fate will find a way for the prophecy of John Quincy Adams to become a beautiful reality; that "the day is not far distant when one language of weights and measures will be spoken from the equator to the poles."

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

ENGINEERS' CLUB OF ST. LOUIS.

FEBRUARY 6, 1889:—301st Meeting.—The Club met at the Washington University at 8:15 P. M., President Meier in the chair, twenty-four Members and two visitors present. The minutes of the 300th meeting were read and approved. The Executive Committee reported the doings of its sixty-fourth meeting, recommending the following applicants for election to membership: Edward E. Wall, Henry Groneman and Nils Johnson. They were balloted for and elected. Applications for membership were announced from Whitfield Farnham, Assistant Engineer of Coal Companies on Missouri Pacific Railway System, endorsed by Lewis Stockett and H. P. Taussig; E. L. Goldstein, Consulting Engineer, endorsed by P. M. Bruner and J. B. Johnson; Frank S. Ingoldsby, Surveyor for City Street Department, endorsed by Geo. Burnet, Chas. I. Brown and M. L. Holman; Richard H. Phillips, of the St. Louis Bridge and Iron Company, endorsed by J. A. Seddon and Wm. H. Bryan. These applications were referred to the Executive Committee.

Mr. Seddon, Chairman of Special Committee on Legislation on Bridge Reform, reported progress. The memorial forwarded to the State Legislature was read. He stated that the proposed bill was now being modified in certain details by the committee in connection with a similar committee of the Kansas City Club. Prof. J. B. Johnson then read a paper on "Cable Conduit Yokes, their Strength and Design." The paper gave the results of a number of tests made on different shapes of yoke at the Washington University testing laboratory. Sketches of the different forms were made, showing where each had failed. The author submitted a design for a new form of yoke composed of cast iron, strengthened by a steel or wrought iron tension member. The cost need not exceed that of ordinary yokes' and seemed to offer a remedy for many of the existing difficulties. In the discussion Mr. Holman spoke of the width of slot in use in this city, that of the Citizens' road being ⅝-inch and of the Olive street line ¾-inch. He thought the proposed design of yoke would prove a success, unless unforeseen complications, due to extreme changes of temperature, were introduced by the use of two separate members. He described the Lane yoke used in Cincinnati, which was very strong: also the Chicago yoke, made of wrought iron tee irons. He stated that the most important question now affecting cable lines was the amount of contraction of the yokes. It was not known whether this would continue indefinitely or whether a permanent shape would be reached, or whether repeated contractions and expansions might be expected. Should the contraction continue, most of the yokes would break, which, with the difficulty of keeping the slot open, would necessitate enormous outlays of capital.

Mr. Bruner gave some data on the effect of ground freezing, and stated also that very little reliable information was to be had on this subject. In his opinion a ¾-inch slot was better than a ½-inch. Mr. Vail gave a description of the yoke adopted by the St. Paul lines, where the frost line was about 6 feet below the surface. Mr. Russell showed that the stiffness of the yoke seemed to have no effect on the amount of slot closure.

Mr. Seddon spoke of the stresses which come upon the yoke, due to the freezing of the ground, and suggested that it would be impossible to design a yoke to

withstand the stain; but as the yokes do stand the service, it showed the need of further investigation.

The question of Transfer of Membership then being taken up the Secretary read letters from the Secretary of the Engineers' Club of Kansas City, regarding the present status of the movement. On motion of Prof. Johnson, the whole matter was referred to the Executive Committee for consideration, and to recommend to the Club a plan of action. Mr. Russell brought up the question of closer organization among the engineering clubs in the country. He gave an outline of the history of previous movements in this direction, with a statement of some of the good results that might be looked for. Considerable discussion followed, in which Messrs. Holman, Seddon, Johnson and Russell took part. On motion it was ordered that the chair appoint a committee of three to devise a scheme for a closer union among the clubs of the association. Messrs. S. B. Russell, J. A. Seddon and J. B. Johnson were appointed such committee.

[*Adjourned.*] WM. H. BRYAN, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

FEBRUARY 4, 1889:—Regular meeting at the Ryan Hotel; President Loweth, ten Members, two visitors present. The minutes of last meeting were read and approved.

Communication from the librarian, recommending that money should be appropriated for the library, was read and placed on file.

A Committee on Membership was appointed, consisting of Messrs. C. J. A. Morris, W. W. Curtis and R. Davenport.

A communication from the Engineers' Club of Kansas City, relating to the exchange of members between the different engineering societies of the Association, was laid before the Society and referred to a committee consisting of Messrs. S. D. Mason, M. Toltz and R. J. Johnson.

The paper of the evening was read by Mr. R. J. Johnson upon the "Testing of Water Mains by the Use of Pressure Gauges."

[*Adjourned.*] GEO. L. WILSON, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

JANUARY 21, 1889:—A regular meeting was held in the Club Room at 8 P. M. President O. B. Gunn in the chair, Kenneth Allen, Secretary. There were present seven Members and two visitors.

Minutes of the last regular meeting and that of the Executive Committee were read and approved.

On canvass of ballots, Henry Goldmark and Gerald Bourke were declared elected as Members.

A. J. Mason reported for the Banquet Committee, arrangements as made for a dinner to be held by the Club, January 28, in the Board of Trade Building.

Letters on transferrence of Members from the various local societies were read by the Secretary. The general tone was in favor of action, and on motion of Kenneth Allen, it was voted that the President appoint a committee to report at the next meeting. Those selected were O. Sonne, W. H. Breithaupt, A. J. Mason.

Mr. Breithaupt reported progress on Bridge Reform. Since the last meeting the Memorial and Proposed Law had been printed and presented as a bill in the State Legislature. A letter had been received from the St. Louis Club stating

that a committee had been appointed to draw up a memorial to the State Legislature indorsing the bill.

The Secretary read for A. N. Connett a paper on "Electric Railways." The Observation Hill Railway, Allegheny, Pa., is in successful operation with 60 per cent. curves of from 40 to 200 feet radius. The maximum grade, 12½ per cent., is on a reversed curve with radii 100 and 200 feet, and is overcome at rate of 6 miles per hour.

The West End Street Railway Company's line, of Boston, was described.

Losses in transmission of power by electricity vary from 25 to 40 per cent. In this, as in wear and tear, cost of construction and operation, electric railways have the advantage of cable railways, but their rolling stock is more costly.

Cost of overhead system about $5,000 per mile, and of conduit system not over one-quarter that of a cable railway.

The Secretary then read for a "A Member" a paper on "Shrinking of Material and Settlement of Embankments." Railroad specifications generally require 10 per cent. added to embankments to allow for settlement. This was considered unjust, especially when required to be removed at contractor's expense. Personal observation corroborated Rankine, Cressy, Trautwine, etc., in that earth takes less room in bank than in cut, and in scraper work it was thought unnecessary to allow shrinkage.

A. R. Meyer, Rollin Norris, A. J. Tullock and R. H. Bacot were proposed as members.

[*Adjourned.*] KENNETH ALLEN, Secretary.

January 28, 1889:—The Club held its annual dinner in the Board of Trade Building at 9 o'clock P. M.

There were present 33 members, as follows: Frank Allen, Kenneth Allen, G. Bourke, D. Boutecou, C. A. Burton, W. H. Breithaupt, J. R. Chapman, John Donnelly, B. W. De Courcy, E. I. Farnsworth, J. H. Grove, O. B. Gunn, F. C. Gunn, Henry Goldmark, H. F. Hill, W. D. Jenkins, H. A. Keefer, W. Kiersted, W. B. Knight, A. J. Mason, B. L. Marsteller, S. A. Mitchell, J. W. Nier, Wm. Norris, G. W. Pearsons, D. W. Pike, W. Stone, C. H. Talmage, J. E. Thomes, F. W. Tuttle, F. B. Tuttle, W. B. Upton, B. R. Whitney, Jr., and as guests, Gen F. E. Sickels, Hon. Henry Smith, R. H. Elliot, C E.; H. H. Jackman, C. E., and representatives of the press.

After a sumptuous dinner toasts were proposed as follows:

"The Engineer: He Holds the Lever that Moves the World." O. B. Gunn.

"The Engineer: The National Public Works He Carries Out." J. W. Nier.

"The Engineer: The Water-Works He Builds." K. Allen.

"The Engineer: The Railroads He Built Before We Were Born." F. E. Sickels.

"The Engineer: Those He has Built Since Then." C. H. Talmage.

"The Engineer: The Materials He Uses." H. Goldmark.

"The Engineer as a Contractor." B. W. De Courcy.

"The Engineer: Kansas City His Home." John Donnelly.

"The Engineer: The Ships He Builds." G. W. Pearsons.

"The Engineer: The Cable Roads He Builds." D. Boutecou.

"The Engineer in War Times." Messrs. Gunn and De Courcy.

"The Engineer in Courts of Law." Hon. Henry Smith.

"The Club." W. B. Knight.

Mr. A. J. Mason was toast-master, and in every respect the affair was thoroughly enjoyed. KENNETH ALLEN, Secretary.

FEBRUARY 4, 1889:—A regular meeting was held at 8 P. M. in the Club Room, there being present 7 Members and 1 visitor.

Minutes of the last meeting and of that of the Executive Committee were read and approved,

Mr. Mason reported favorable progress for the Committee on Transfer of Members.

On canvass of ballots Messrs. Rollin Norris, A. J. Tullock, R. H. Bacot and A. R. Meyer were elected Members.

On recommendation of the Executive Committee, Messrs. O. Chanute, Geo. H. Nettleton and Chas. F. Morse were elected Honcrary Members.

A paper entitled "The Details of Iron Highway Bridges" was read by E. W. Stern, and discussed, bringing out the especial merits of the Schwedler Truss for long spans and describing details of ordinary practice.

John E. Thomes, James R. Chapman, F. E. Sickels, E. A Harper, R. H Elliot and L. P. Root were proposed as Members.

[*Adjourned.*] KENNETH ALLEN, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

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THE HISTORY OF A HIGH VIADUCT.

By S. D. Mason, Member of the Civil Engineers' Society of St. Paul.

The locating engineers of the Northern Pacific Railroad, from the summit of the Rocky Mountains westward to Lake Pend d'Oreille, a distance of 288 miles, found the general route plainly marked out by the water courses tributary to the Columbia River, and by following down the Little Blackfoot, the Hellgate, the Missoula and the Clark's Fork rivers, developed an easy practicable line with moderately light work, low grades and good alignment for the heart of the continent. There is, however, one notable exception to this regular descent caused by the difficulty of building a railroad from Missoula down the Missoula River to its junction with the Clark's Fork. The stream is wide, rapid and shut in between walls of rock, which, as one engineer complainingly puts it, stand like slates on a steep roof and afford no chance to set up a transit. Aside from the forbidding natural features which would render construction difficult and expensive, the river swerves suddenly from its northwesterly course, upon meeting a severe rebuff from the Bitterroot Mountains, and turns disappointedly almost due east for some ten miles before falling into the arms of Clark's Fork. No amount of money or engineering skill could seduce it to cut a roadway through the rugged country south of Lakes Pend d'Oreille and Cœur d'Alene.

An alternative route was open: to leave the valley of the Missoula near the town of that name, climb by two and two-tenths per cent. maximum grades through a narrow, well-wooded gorge, called the Coriacan Defile, to the head-waters of Findley Creek, thence down that stream, down the Jocko and the Pend d'Oreille rivers to the Clark's Fork at the mouth of the Missoula. This was the line favorably mentioned by the lamented W. Milnor Roberts, when Chief Engineer, and considerable expenditure of time, shoe leather and money in explorations demonstrated it to be the cheapest and best route, and it was adopted. It is on this portion of the railroad that the subject of this paper, Marent Gulch Viaduct, stands. It received its name from the nearest inhabitant, an old Frenchman, who had a cabin on the small stream that flows through the gorge. There is a tradition that the defile received its name from an unfortunate Kanaka called Coriaca, who was killed here by the Indians

while on his way from the Kootenai country with a party of traders. If true, his bones rest a long distance from his native isles.

Marent Gulch is the largest ravine of these foot-hills of the Rocky Mountains. A great many preliminary lines were run to see if the road could be located to avoid crossing it, but it was impossible to build around it, so a high wooden trestle was determined upon and was located at the most eligible crossing. The surrounding mountains are covered with fine pine timber, from which the one million and four thousand feet board measure of timber was cut which went into the original structure. Fifty-eight tons of iron came from Portland by rail to end of the track, and was hauled by team eighty miles over bad roads to the site of the structure.

A preliminary design for a wooden structure was made by Mr. C. C. Schneider, of New York, from which the details were developed by Mr. H. J. Howe, at Missoula, under direction of Mr. I. S. P. Weeks, the Division Engineer. The original wooden bridge has been replaced by an iron one, and here the subject naturally divides into three chapters, viz., the Past, the Present, and the Future; the third chapter, you will be glad to learn, will be a very short one.

THE ORIGINAL WOODEN VIADUCT.

In the fall of 1882, detailed plans were made for a wooden trestle 866 feet long, 227 feet high, with a track on a grade of 104 feet per mile, making a rise of about 17 feet in the length of the bridge. The track crosses on a tangent, running down from a 4-degree curve at the west end into a 7-degree curve 1,400 feet beyond the east end of the structure. When built, this was the highest wooden trestle in America. The bottom and sides of the gulch are rocky, affording good foundations for mud sills. Eight wooden towers were designed of varying heights to suit the ground and to form supports for seven Howe truss spans of 50 feet each.

These towers were 20 feet across on the line of the bridge, the sides resembling two Howe truss bridges standing on end and inclined from the bottom with a batter of one in six toward each other at the top. From a point midway between the foot of these trussed sides rose two secondary sides of similar design, inclined outward and meeting the main sides 48 feet below the cap. Auxiliary posts and struts helped distribute the vertical load over the bottom sill, but in their main features these towers, when viewed longitudinally with the bridge, presented the well-known "M" type of bent, tied together every 16 feet in height with horizontal cross braces, and with a trestle bent 48 feet high on top.

The main posts were two 12 by 12 sticks, in 23 feet lengths, packed 6 inches apart and bolted together. The secondary posts were 8 by 12, packed. The packing blocks were cut to act in tension as well as compression, a refinement which we think might have been dispensed with in framing these tower posts, as no pull could come upon them. This would have cheapened the framing.

The 50-foot Howe trusses carrying the track from tower to tower were of the ordinary form, 10 feet in total depth with panels 8 feet 2 inches long.

The transportation of iron such a long distance rendered it necessary to economize its use in every possible way, and with this in view, the angle blocks were made of the dryest fir obtainable. These subsequently gave trouble by shrinking in seasoning, and ultimately obliged us to put a second system of trusses with iron blocks, outside the original ones. The track floor was supported on the upper chord of the trusses, over the pannel points.

This system of eight towers and seven trusses carried the track over the deepest part of the gulch. The approaches at either end were straining beam spans of 30 feet each, supported by trestle bents of the "M" form. The general arrangement of towers and bents was made with the view of permitting the structure to be replaced at some future time by an iron one, without delay or interruption to traffic. As soon as the bills of timber were prepared, a contract was made with Bonner, Hammond & Co., of Deer Lodge, Mont., who at once put several portable saw mills in the mountains near the gulch and commenced work. Mr. S. J. Wallace, of St. Paul, was made general superintendent of framing and erection.

The place of work was rugged and isolated. Missoula, the nearest town, was thirteen miles away, the railroad some eighty miles from the place on the west, and much further towards the east. But as soon as operations commenced the usual frontier settlement sprung up, consisting principally of boarding-houses, saloons, dives and gambling places, all of which flourished off a gang of well-paid carpenters and loggers, who received from six to seven and a half dollars per day. This evanescent town has now entirely disappeared, only the cabin of old Marent remains, and looks like a toy house when viewed from the train. The small stream called Marent brook winds under the bridge and along past the house; at its maximum it is perhaps 20 feet wide and 2 feet deep.

Mr. Wallace and his gang of carpenters passed through Missoula on Christmas day, 1882, and commenced work the next day. The timber was framed at the mills as cut, then marked and hauled to the bridge. The bents were framed flat. The joints were adzed and then planed. Trial pits were dug to test the foundation, and it was found excellent. The ground is a cemented gravel, so compact as to render pile driving unnecessary. The tower bents rested on mud sills, laid close together. The side slope of the hill necessitated digging into it on the higher side a depth of 18 or 20 feet to get the sills horizontal. The engineer in charge, Mr. Arthur P. Mitchell, allowed one inch for settlement after all sills were in place, and as this proved ample, the excellence of the foundation and close joints of the framing was practically demonstrated. This is a remarkable circumstance in a structure 227 feet high with such a multiplicity of butting joints. The pits were filled with earth over the sills, now condemned as bad practice, as tending to rot the most difficult parts of the structure to renew long before the upper works deteriorate.

After the big wooden puzzle was framed at the mills, the pieces were marked and hauled as wanted to the erectors, who raised them in place with help of gin poles 48 to 52 feet long. The heaviest pieces to raise were 12 by 12 sticks, 36 feet long, weighing about 1,700 pounds. From two to four erecting gangs of sixteen men each were employed, who, as

their work rose in the air, become accustomed to the elevation and used to walk across on the iron rods a distance of some 20 feet, and 200 feet from the ground.

When the structure was about 30 feet from the top, the men conceived that their wages should be raised to correspond with the increased altitude, and accordingly struck for ten dollars per day. The Division Engineer says they had him where the hair was very short, track was coming up close, and there was no time to educate a lot of new men. Only those who had grown up with the bridge could work 220 feet in the air. The matter was compromised and the head striker discharged. We are happy to add that this man is now working on shoes in a Massachusetts town for one dollar per day.

The absence of false work during erection gave a striking effect to the work, so much so that Henry Villard, when making his first trip over the line, was impressed by what he termed the "slenderness, lightness and airiness" of the structure. He was not the only one to wonder if it was sufficiently strong. The carpenters predicted injurious vibration and possibly buckling of the sides of the towers; but their fears were unfounded; the structure was rigid and firm. The plan was demonstrated to be practical and good. The bolts had countersunk heads with beveled cast washers underneath which gave an extremely neat, finished appearance. The experiment was tried of raising one of the 50-foot trusses, bodily from the ground to its seat, but the plan was found impracticable. The chords were without splice, 56 feet long over all, built of one 8 inch by 12 inch and two 6 inch by 12 inch sticks packed and keyed. These chords were first placed in position and held by struts and guys, while the braces were put in, commencing at the middle of the span instead of at the ends, as is the usual practice. The deflection of these spans under a locomotive was about one inch. Both horse-power and steam-power were used in lifting the timbers to place. The amount of line and tackle necessary for hoisting and staying the bents was enormous, and the coating of ice and frost which frequently covered the ropes rendered work difficult in the early mornings.

The floor system had no special features. Floor beams in pairs, each 9 inches by 16 inches, 16 feet long, supported main and jack stringers, across which were placed bridge ties 6 inches by 8 inches, 16 feet long, spaced six inches apart. Guard stringers, nine inches outside the rails, were notched and bolted down to the cross ties. Plank walks, railing and water barrels were provided and the completed structure was crossed by the track on June 15, 1883.

This event was made a gala occasion by the whole country around, many of the inhabitants then seeing a locomotive for the first time, and some of the engineers for the first time in twelve months. Incidents were not wanting on this festive day, but to recount them in detail would be quite foreign to the scope of this paper. An army officer from Fort Missoula was overcome by dizziness when in the middle of the bridge, and crawled on hands and knees over the ties to *terra firma*. When the engine stopped midway on the trestle and was blowing its exultant whistle, an anti-prohibitionist who had been working his way with many a slip and fall up the steep hillside, finally gained the track and reeled

his way along the guard rail on the very ends of the ties to the iron car, while all the spectators held their breath. As a trapeze performance the exhibition deserved considerable applause.

The total cost of the viaduct was $85,620 and the time spent on framing and erection was 171 days, during winter and spring of 1882-3. The quantities of material and detailed cost were as follows:

Wages of carpenters and laborers	$36,336	
Wages of engineers and assistants	3,135	
Total labor		$39,471
756,300 feet B. M. sawed timber.		
213,300 feet B. M. hewed timber.		
970,000 feet B. M. in all (say)		
869,000 feet B. M. timber, at $27	23,463	
101,000 feet B. M. timber, at $16	1,616	
Total timber actually used		25,079
87,120 pounds wrought iron, at 5¾ cents	5,010	
29,940 pounds cast iron, at 3¼ cents	973	
117,060 pounds freight from end of track, at 2¾ cents	3,220	
Total iron and wagon freight		9,203
Supplies for men		2,860
Blocks, ropes, chains and wrenches		1,300
Forty horses 90 days, each at $1		3,600
Hay and oats for same		2,700
Rent of land and land damages		400
Traveling expenses of engineers, and office and sundry miscellaneous expenses		1,007
Total cost		$85,620

Or $88.27 per thousand feet, board measure.

There was some question, at first, about obtaining the requisite quantity of timber in time. But enough was found within a radius of five miles, and much of it hauled after snow fell. Necessarily, it was green to work and occasioned some trouble later on by checking. The tendency to spring out of line, due to unseasoned timber, was overcome by temporary clamps and bolts. The sticks in the shore bents were hewed instead of sawed, in order to hasten the work. The wooden angle blocks in the Howe trusses were made of what was called "fir," supposed to be better for the purpose than the native Norway pine. These blocks were hewed out in lengths of 14, 16, or 18 feet, and then sawed off to required lengths. They were got out early and painted. Possibly they were painted too soon, which prevented the sap from evaporating; or perhaps the nature of the wood occasioned the trouble soon experienced by these blocks shrinking and letting the trusses sag. The blocks showed no signs of suffering from undue crushing strains. The diagonal braces between sides of towers, footed also against blocks of fir, and although held in place by dowel pins, were apt to get loose as the woodwork seasoned, requiring frequent tightening of the iron rods.

THE PRESENT IRON VIADUCT.

The wooden structure remained in good order in every respect, excepting the shrinking of the angle blocks previously alluded to, and for this reason new trusses, with iron blocks, were placed alongside the original trusses in June and July, 1884. Still, the management of the road felt much uneasiness at the constant risk from fire; and, indeed, the loss of the trestle, combined with the contingent damage arising from the great interruption to traffic that would have resulted therefrom, was incal-

culable. The configuration of the ground, at the Gulch, would render transfer of freight impracticable and transfer of passengers a great annoyance. The necessity of a permanent iron structure was promptly recognized, and in the latter part of 1884, a new structure was designed by Mr. George S. Morison, the local work placed in charge of Mr. Alfred Noble, and Mr. George A. Lederle was made inspector of shop work.

The iron structure was so designed that it could be erected on the line of the wooden one, with but few changes in the latter; these comprised moving toward the centre line the double trusses of the spans, changing a few batter posts in the approach bents, and supporting the wooden towers while excavating near them for foundations for the new ones. The existence of a structure at the site, from which the new one could be erected, made it possible to use economically longer spans and fewer bents than is usual in such structures. The distances between centres of the iron towers were made double those between the wooden ones.

The iron structure consists of four plate girders, each 30 feet long, making a total for the four of 120 feet; five spans, each 116 feet 8 inches, 583 feet 4 inches; girders, 23 feet 4 inches long over each of the four towers, 93 feet 4 inches; total length, 796 feet 8 inches, or 69 feet 4 inches shorter than the wooden bridge.

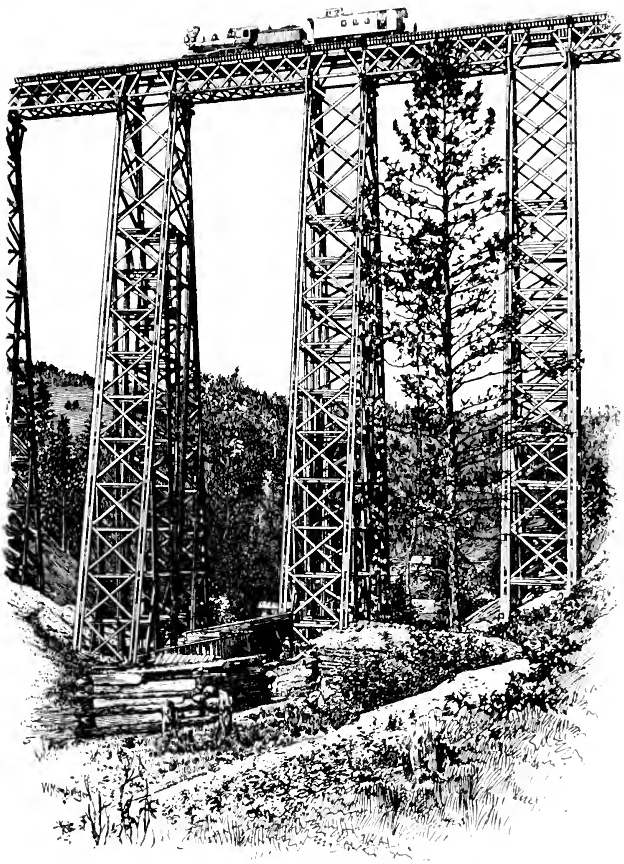
The sub-structure consists of 24 masonry piers, supporting four iron bents and four iron towers which vary in height from 17 feet, for the bents nearest the abutments, to 180 feet for the towers in the bottom of the gulch. The two abutments are also of masonry.

A careful re-examination was made of the character of the material for foundations at the sites of the several piers. In the bottom of the gulch the material was better than anticipated; while in places on the sides of the slopes, it was found necessary to remove partially decayed rock in order to reach that of suitable character. The railroad crosses the gulch nearly at right angles, and the side slopes are almost exactly alike, as is rendered apparent by the remarkable symmetry of the structure; the towers, bents and spans, from the centre to each abutment, being exactly similar. This peculiar topographical feature may have resulted from chance, or may bear evidence to the good judgment of the engineer who selected the location. At all events, it it simplified planning and erecting the new work.

The iron work was manufactured by the Union Bridge Company at their Buffalo shops. The stone was supplied by Messrs. Breen and Young, of St. Paul, except the granite in the abutments, which came from stock owned by the Railroad Company. The work at Marent was done entirely by hired labor and was commenced about September 1, 1884. It was in general rendered expensive by the cost of handling materials to the places where used, and by the precautions necessary to insure safety of the existing structure. Some delays were experienced in receipt of stone and iron, which added to the cost.

The Foundations.—Two piers in the bottom of the gulch, D4 and D3, rest on pile foundations: each foundation has 16 piles, all driven to refusal and probably to bed rock. These are cut off below permanent water level, the material excavated one to two feet below the cut, and concrete blocks, 18 feet square at the base and 12 feet square at the top,

built up in place around and over the pile heads. The concrete is composed of one part Portland cement to three parts of sand, with as many boulders as could be thrown in by hand, the boulders not amounting to 30 per cent. of the whole volume. Mortar for concrete was mixed by a spiral worm machine. A sample of the concrete, knocked off with some difficulty with a pick, shows it to be a first-class artificial stone. The piers E1 and E2, also in the bottom of the gulch, rest on concrete bases,



Marent Gulch Viaduct.

each 12 feet square, founded on hard pan. The remaining piers and the abutments rest on bed rock. Where concrete blocks are used they are from 10 to 16 feet square, depending on the nature of the rock and the weight to be carried.

The amounts of excavation and concrete are as follows: Excavation, earth and gravel, 3 689 cubic yards; excavation, rock, 1,645 cubic yards; concrete, 544 cubic yards.

The work was laid out from the old viaduct. It was found impractica-

ble to drop points to the bottom and sides of the gulch by plumb-bobs, as a very slight breeze threw them several inches from the vertical. It was accomplished by using two transits, carefully adjusted, to carry longitudinal and transverse lines to an intersection on the ground, by the vertical movement of the telescopes. In this way, centres were established, from which the pits were laid out and working lines given.

The Masonry.—The abutments are faced with granite which was left over from Snake River bridge, and the backing is of quartzite obtained near Evaro station. The piers are built entirely of cut limestone, coping in single pieces, courses below generally in two pieces. The copings under the principal towers are single stones, each 7 feet square by 20 inches thick, or a trifle over three cubic yards in volume, and weighing about 13,000 pounds. To handle these stones down the steep sides of the gulch was somewhat difficult, decidedly tedious and quite risky. They were slidden down on a temporary track of iron rails, and held back by wire ropes. On one occasion a coping got loose, slid down the side of the gulch on the snow, which at that time covered the ground, and added to the difficulty of handling. This runaway stone struck and cut cleanly off a leg of one of the timber towers, and barely missed a leg of one of the iron towers, which had just been placed in position. The shock shook the timber structure so violently that every one on it ran hastily for the land.

Two-inch anchor bolts, grouted in, extend the full height of each masonry pier, binding the courses firmly together, and each pier has four one and one-quarter inch dowels connecting the upper four courses. At the lower end, the anchor bolts are held by round cast-iron disks, imbedded two feet into the concrete; the tension is brought by screwing down nuts on the upper ends, to a bearing on cast-iron washers resting on the masonry.

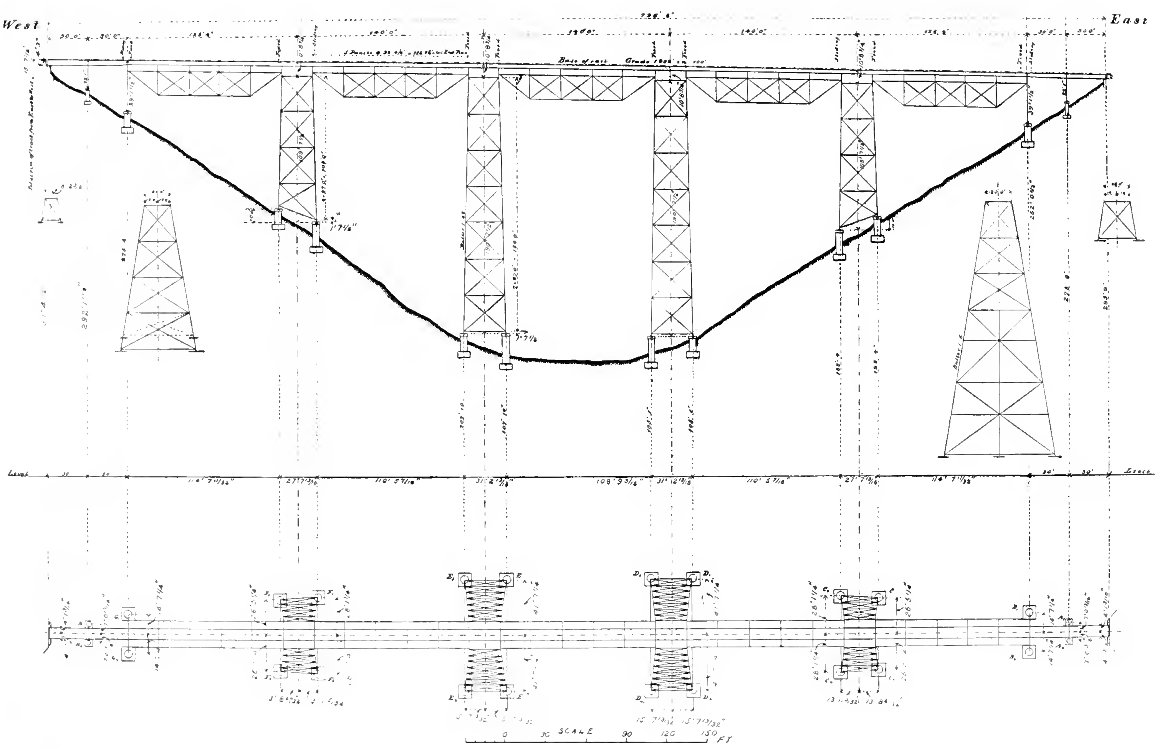
The Iron Work.—The erection of the towers was commenced in December, 1884. The spans were placed in March, 1885. The new floor system was completed in April. In erecting the towers, the tops of the posts of each section were supported by timbers thrust out from the old towers, until the braces and diagonals could be put in. This made a very cheap false work. The pieces were lowered from a derrick car having two derricks; a piece was lowered from each side of the car at the same time. The car was handled by a locomotive.

The amounts of iron and steel in the superstructure are as follows:

Towers and bents	872,900 lbs
Superstructure, including floor beams and stringers	813,650 lbs
In all	1,686,550 lbs.
The total cost, exclusive of traffic charges on material over the Northern Pacific Railroad, was	$153,362.16

The cost in detail, was:

Foundations	$21,664.59
Masonry	30,079.81
Towers	49,188.44
Superstructure	36,593.94
Floor	4,807.43
Painting	1,826.74
Engineering and incidental expenses	9,085.15
Permanent track	116.06
	$153.362.16
The traffic charges, for transportation of material over the Northern Pacific Railroad, at one per cent. net ton per mile	$24,743.18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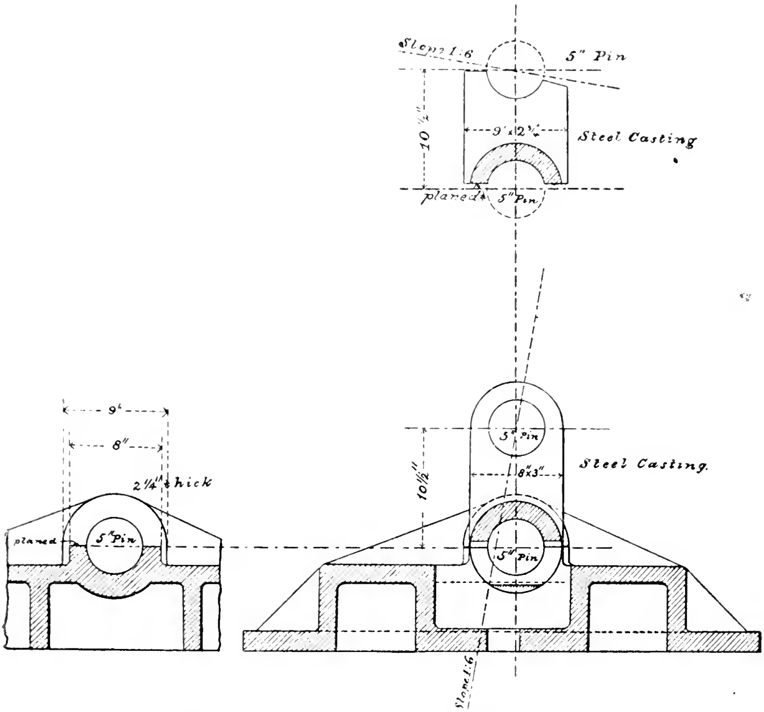
The cost of removing the wooden structure after the iron one was completed was $7,663.64. The old material was piled up at Evaro, a station at the summit of the steep grade and three miles west of Marent. The 50-foot Howe trusses have been used on branch lines for crossing small streams. The iron work cost 3.85 cents per pound, delivered at St. Paul, and the stone $16 per cubic yard on board cars at Minnesota Transfer. Foreman of erecting gang received $180 per month, and skilled labor from $3 to $4.50 per day. The men were boarded for $6 per week at a mess house run by the company. At this rate the company



Details of Rocker at Base of Tower Posts.

lost $777.84, which sum is included in cost of the work. The cost of erecting, repairing and removing the temporary buildings in which the men were fed and lodged, and the engineer's office shanty was $2,702 31. The depreciation in value of the plant at the close of the work was estimated to be $4,483.18. Both these latter amounts are included in the total cost.

One peculiar noteworthy feature of the iron structure, is the provision for expansion and contraction of the long struts connecting the sides of the principal towers. Each "down stream" leg (as it might be called) rests upon a steel rocker—shown in the detail drawings. It resembles a short link, extending up into the foot of the post, and connected there

by a five-inch cast steel pin. The lower end of this rocker or link bears upon another five-inch steel pin, resting in a cast-iron base bolted to the masonry.

The tower posts batter in two directions. The struts connecting the feet of posts are built of channels and lattice work. The posts of the towers are in lengths of about 27 feet between the faced ends; they are built of plates, angles and lattice work, into rectangular form, varying in net section, from top to bottom, from 40 to 50½ square inches.

Each panel length, in height, is strutted and sway braced both laterally and longitudinally. The strut connections are made by steel pins. The plate girders and deck spans are provided with expansion rollers at four points in the whole length of the bridge. The deck spans are pin connected.

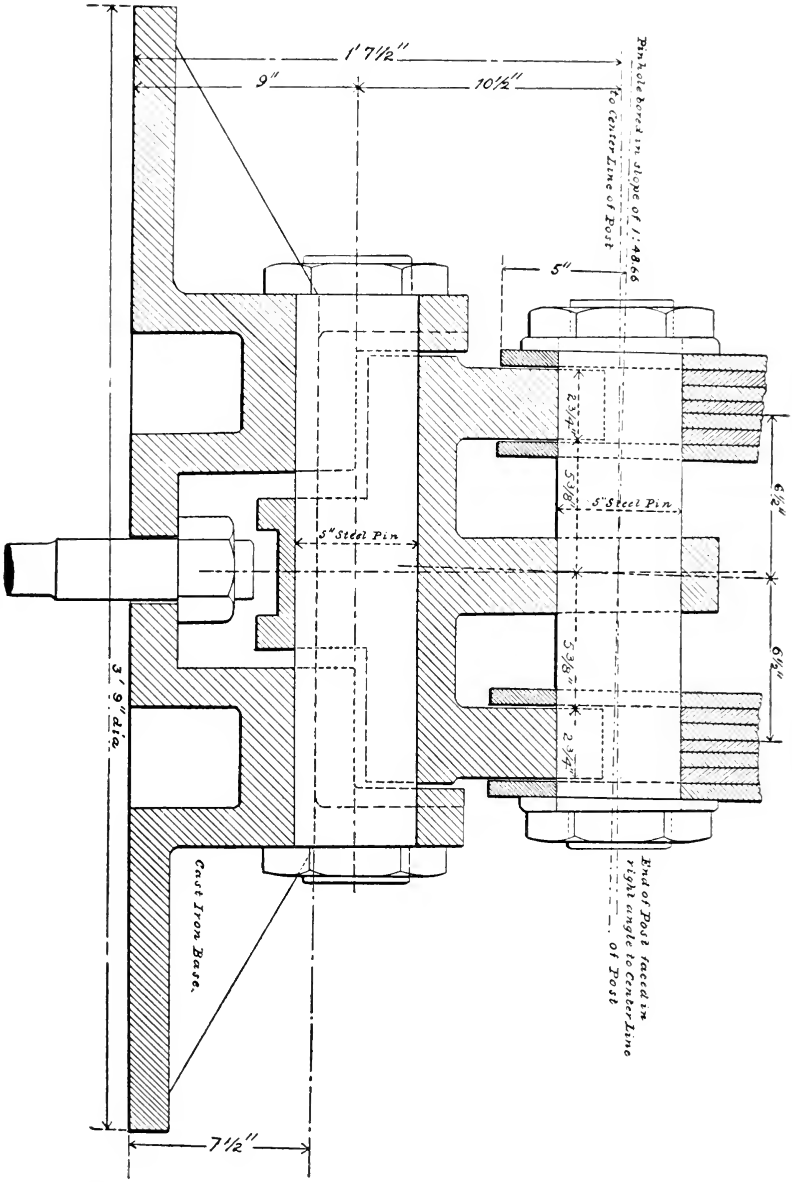
The track is laid upon 9 inches by 9 inches by 12 feet cross-ties, spaced 14 inches from centre to centre. Guard rails of 4 inches by 5 inches angle iron are bolted through to every tie, and are brought together, in centre of track on the road bed, some distance beyond each abutment. Slip joints are provided in this guard rail over each pair of expansion rollers. The whole iron work received one coat of Cleveland Iron-clad paint after erection.

The new structure was placed in position without delaying passenger trains, and but few freights, which were unavoidably held while the new floor system was being put in. A fatal accident befell C. E. Healy, foreman of erection, who fell about 175 feet to the ground, on the 3d day of April, 1885. He struck one of the towers in falling, and life was extinct when his men reached the body.

During the summer months of 1885, an intelligent watchman was kept at the structure, to report its behavior under variations of temperature, and to notify the engineer-in-chief of rods needing adjustment, loose rivets, movement of spans on their rollers, action of rockers, and other phenomena incident to the new work. That his employment was agreeably diversified, may be judged from his report of October 23, 1885, in which he says: "Shooting is good this fall; I have killed five deer." This helps us appreciate the wild and solitary locality in which so much money has been expended. The work was so well planned and so carefully erected that the watchman had but little adjustment to make. All the rods in the towers were tightened, and some of the counters in the spans. The sliding ends and the rockers worked well. No loose or missing rivets have been reported.

The structure has been very carefully inspected semi-annually—generally early in the summer and late in the autumn—in order to take advantage of a wide range of temperature. At the last inspection the piers were found in first-class condition, showing no evidence of settlement or movement. The wooden ribbons or guard rails on the floor were originally laid with a space of about one inch between the ends over the expansion rollers. It was observed the first season that the floor had begun crawling down grade, and in course of one year these guard rails butted tightly together. The entire floor system moved down hill about two inches. A peculiar feature was noticed in movement of the track rails, one of which moved up hill and the opposite one

down hill. This same movement has been observed on other steep grades of the same division, and has never been satisfactorily explained.



Marent Gulch Viaduct—Details of Rocker at Base of Tower Posts.

The track was originally laid with 56-pound rail and plain splices:

since it has been replaced with heavier rails and angle splices, the crawling movement has practically ceased. The structure appears very rigid under passing trains, the vibration of the sway rods is not noticeable and the lateral motion hardly perceptible. Special rules prohibit engineers and trainmen from applying the brakes suddenly while their trains are upon the bridge.

THE FUTURE EARTH EMBANKMENT.

As this will require handling something over one million cubic yards of material, and as the iron structure should last for several generations, we can safely leave the pleasure of writing this chapter to our posterity.

In conclusion, I trust the profounder wisdom of my auditors will extract from these flowers and weeds of simple narrative, something befitting the elevated nature of the theme.

WROUGHT IRON AND STEEL EYE-BARS.

By Carl Gayler, Member of the Engineers' Club of St. Louis.

[Read January 16, 1889.]

The American system of bridge building differs from that of European countries in the use of tensile members, specially formed to resist in the simplest and most effective manner the strains which they have to bear; tensile members of bridges in Europe being built in very much the same manner as compression members. This difference is thoroughly characteristic, and as marked as, to cite an analagous case, the difference between American rolling stock and locomotives with their buggy system, so admirably adapted for the conditions of the track and traffic, and the European cars and engines with their rigid carriage system. My intention is not to enter into the old dispute over the superiority of either of the two methods. We American engineers are convinced that, at least for long spans, our pin-connected bridges are theoretically, practically and commercially preferable to the European bridges, which rather pleasant feeling, however, should, in view of the importance of the subject, not make us averse to familiarizing ourselves thoroughly with the weak as well as with the strong sides of the same. The following remarks, though they may not contain much which is new to some of you, may not be unwelcome, as they are mostly based on actual observation and experience.

The process of making a wrought-iron eye-bar is simple enough : A head is formed at each end by forging, hammering or upsetting, through which head a hole is drilled for the pin, but the eye-bar is of such importance that we need not be surprised that the most eminent engineers of the country have contributed their share toward establishing sets of rules for the proper shape of the head, aided therein by tests on the powerful testing machines of our larger shops. Theoretical investigations have not been wanting, but as a matter of fact, we owe them, on this particular subject, but very little. It is the testing machines, not theories, which have advanced our knowledge of the properties of eyebars, in direct distinction from the pins, for the proper dimensioning of

which we rely altogether on the theoretical laws of resistance against bending.

The shape of eye-bar heads, as used originally, was probably circular, the diameter of the head being equal the diameter of the pin, plus the width of the bar itself. The failure of such heads under the testing machine brought about the following modifications:

1. A considerable increase of width of head in the axis of the bar back of pinhole *a*, Fig. 1.
2. A somewhat smaller increase of width *b*, Fig. 1.
3. The use of a larger radius *R* of neck.
4. For a greater ratio of the diameter of the pin to the width of the bar all the dimensions of the head were very much increased.

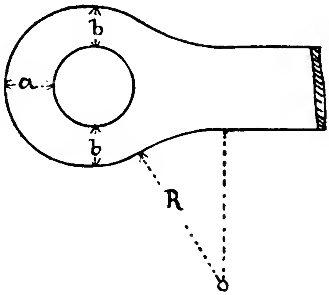


Fig. 1

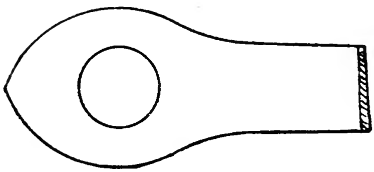


Fig. 2

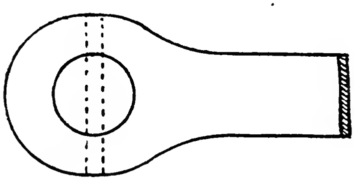


Fig. 3

These four modifications cover all the improvements ever made on the shape of iron eye-bar heads, and it is immaterial which of the shapes, preferred by the leading bridge companies, is used—the one introduced by Shaler Smith with a pointed end back of pin (Fig. 2), the one most generally in use, shown in Fig. 3, or simply a circular head, as long as the areas required by the four points stated above are properly covered.

In the mode of manufacturing the heads, the forging process under the steam hammer has proved to give better results than the upsetting alone without subsequent hammering. This might have been expected.

The making of a wrought iron eye-bar head requires work. The steam hammer has to do on a large scale what the blacksmith does by hand when forging or welding. It is not sufficient to make the heated material flow into its new shape, but a fibrous structure has to be produced in it. In this new structural condition lies the success of the strength of the head, and this explains the great care which is required in turning out great numbers of uniformly good iron eye-bars. To make the heads under the hammer, one or more iron plates are laid on the ends of the bar, which latter reaches to the end of the head. The bar, together with these plates, is then heated to a welding heat and brought under the hammer. It is obvious that unless these piling plates are of as good material as the bar, the head will be inferior; it is also necessary that the direction of the fibres in these plates shall be the same as that of the bars themselves. This latter point is important, and generally there is not enough attention paid to it. Results as good as by the method just described have been obtained by a combination of upsetting and piling and also by mere upsetting; in either case, however, the work of the steam hammer on the ends of the bar thus thickened forming the principal part of the operation.

Supposing now that an iron eye-bar is made with the heads of a proper shape and of good material and work, what is its value? Can the elastic limit and the ultimate strength of the bar proper be reasonably taken as expressing the value of the finished eye-bar (inclusive of heads), or is there some deduction to be made? I think there is some such deduction to be made for the following reasons: Chemical impurities in the iron have a more deteriorating effect in the complicated welding and shaping process of the heads, than in the rolling of the bar itself. Specimens for tests cut from the bar may come up to all our requirements, and yet this same iron may not be fit to make a good head. Small quantities of phosphorus, and even more so of silicon, may not lessen the strength and ductility of the bar and yet make themselves felt in the welding and fibre-making process in the head.

Another point is not less important, as it affects directly not the ultimate strength (which in reality is of secondary importance), but the elastic limit. In testing the full-sized bar we can easily tell when the elastic limit is reached, either by direct measurement or by observing the sudden retardation in the rising of the mercury in the gauge, but there is generally no attention paid to the elastic limit reached in the head of the eye-bar, through the concentrated pressure of the pins on the semi intrados of the head. The importance of this point can hardly be overestimated. The only tests which I ever had made on heavy eye-bars, where the diameter of the pin was three-quarters of the width of the bar, gave the surprising result that a permanent, measureable impression of the pin into the bar-head had been made under a strain of only 15,000 pounds per square inch of bar proper.

The effect of unequal heating, *i. e.*, of the heating of the ends of the bar while the bar itself is not heated, can be stated as follows: Taking a number of eye-bars, the heads of which are stronger than the bars (as they should be), and testing them to destruction, we will find that a certain ratio of this number will break at the end of the neck, or, to be

more precise, at that point where the effect of the furnace fire ceased. They will break at that point, too, under a somewhat smaller strain than the bar itself would have developod. For these reasons we are not justified in considering the strength of a finished iron eye-bar to be equal to that of the bar proper, and some allowance for this difference should be made in our unit strains.

But the wrought iron eye-bar has had its time; steel is rapidly taking the place of iron, and it will not be long before it has superseded iron for pins and eye-bars as completely as the steel rail has taken the place of the old iron rail—and we have no cause to regret this change. Any engineer, who has had for a length of time to do with iron eye-bars, and has convinced himself, through tests, of their value, has, from time to time, met with a lot of bars, sometimes from the most reliable bridge firms, which gave surprisingly bad results; he has, furthermore, among a number of good eye-bars nearly always found a few inferior heads, and if he also recalls to his mind the various fractures in their heads, invariably partly crystalline, often not thoroughly welded and the layers of the piling plates discernible, he will feel little reluctance against trying a new material. The long record of tests of iron eye-bars, manufactured for the more important structures of our country, shows results which are anything but reassuring, and it is not too much to say that iron eye-bars, made by our leading bridge companies, under close inspection and with careful tests on the part of the engineer, are more unreliable members than any of the rolled or built shapes, used in any other part of the bridge. Steel eye-bars have doubtless their weak points also, but we have at least the satisfaction of knowing that the material which we are on the point of abandoning has never satisfied us.

In deciding on the use of steel for eye-bars we have to keep in mind that we deal with a superior, but also with a more sensitive, material. To two of the sources of weakness in iron eye-bar heads, which we have stated above, *i. e.*, to the effect of unequal heating and to that of chemical impurities, is added the effect of overheating, the proper degree of heat for steel work of any kind being of the greatest importance. The effect of unequal heating is counteracted by the annealing process, *i. e.*, by heating the whole bar, when completed, but before the final boring of the pin-holes, in a large oven and then allowing it to cool off slowly. This annealing process is also claimed to restore to some extent the strength of the overheated metal, although I am unable to say how far this claim is justified. As far as chemical impurities are concerned, the influence of too much phosphorus is fatal. Bridge companies have found it necessary to insist on steel containing not over $\frac{4}{100}$ of one per cent. of phosphorus.

The difference between the making of an iron and a steel eye-bar head is characteristic of the two materials. As we have seen, the former is essentially a welding and forging process; the latter is a process by which the heated metal requires merely to be pressed or made to flow into its new shape. Upsetting and shaping, both under hydraulic pressure, with such additional hammering or rolling only as is necessary for a surface finish, suffice to make the steel head. *What work is to the iron eye-bar head is heat to the one of steel.*

TESTS OF STEEL EYE-BARS FOR GRAND AVENUE BRIDGE, ST. LOUIS, MO.

April, 1888. TESTING MACHINE OF UNION BRIDGE COMPANY, ATHENS, PA.

Number of test.	Size of bars.	Length back to back of pinholes.	Diameter of pin-holes.	Actual section.	Fractured section.	Per cent. of reduction	Elastic limit per sq. in.	Ultimate strength per sq. in.	Elongation in 12 feet.	Per cent. of elongation.	Remark: Excess of head over bar — 40 per cent. FRACTURE.
1	8″×1⅞″	15′6.3″	5⅞″	14.87 sq. in. 7.95″×1.87″	14.06 sq. in. 7.77″×1.81″	5.4	35,800	53,000	0′6.9″	4.8	27″ from back of pinhole coarse granular (broke off square).
2	8″×15-16″	"	"	7.38 sq. in. 7.94″×0.93″	3.68 sq. in. 6.14″×0.60″	50.1	35,400	59,000	2′4.1″	20	80 per cent. silky, 20 per cent. fine granular (broke in bar).
3	8″×⅞″	"	"	6.83 sq. in. 7.94″×0.86″	3.33 sq. in. 6.52″×0.51″	51.2	36,100	61,200	2′6.8″	21	Silky (broke in bar).
4	8″×1⅝″	"	"	12.82 sq. in. 7.96″×1.61″	6.30 sq. in. 6.12″×1.03″	50.8	36,600	61,800	2′2.0″	18	75 per cent. silky, balance granular.
5	8″×1¾″	"	"	13.58 sq. in. 7.94″×1.71″	6.22 sq. in. 5.98″×1.04″	54.2	31,200	56,900	2′4.1″	20	" " " "
6	8″×1½″	"	"	11.78 sq. in. 7.96″×1.48″	6.89 sq. in. 6.44″×1.07″	41.5	37,400	60,700	2′1.6″	18	50 " " " " (broke in bar)
7	8″×1⅞″	"	"	14.98 sq. in. 7.96″×1.87″	14.07 sq. in. 7.73″×1.82″	5.5	36,800	53,400	0′7.8″	5.4	27″ from back of pinhole coarse granular (broke off square).
8	8″×15-16″	"	"	7.40 sq. in. 7.96″×0.93″	3.27 sq. in. 6.29″×0.52″	5.6	33,400	57,900	2′0.3″	17	Silky (broke in bar).
9	8″×1⅝″	"	"	12.80 sq. in. 7.95″×1.61″	10.83 sq. in. 7.37″×1.47″	15.4	35,000	58,000	1′9.4″	15	Granular, broke off square (in bar).
10	8″×1½″	"	"	11.86 sq. in. 7.96″×1.49″	7.25 sq. in. 6.42″×1.13″	39.	38,700	62,000	2′2.9″	19	50 per cent. silky, balance granular (broke in bar).
11	8″×1⅝″	"	"	12.80 sq. in. 7,95″×1.61″	7.07 sq. in. 6.20″×1.14″	45.	35,300	60,000	2′8.7″	23	60 per cent. silky balance granular (broke in bar).
12	8″×1¾″	"	"	13.85 sq. in. 7.96″×1.74″	8.15 sq. in. 6.47″×1.26″	41.4	36,300	64,200	2′5.7″	21	75 per cent. granular at both ends (broke in bar).
13	8″×1¾″	"	"	13.77 sq. in. 7.96″×1.73″	8.20 sq. in, 6.37″×1.29″	40.4	36,100	62,000	2′7.5″	22	50 per cent. silky, balance granular (broke in bar).
14	8″×1¾″	"	"	13.81 sq. in. 7.95″×1.75″	8.84 sq. in. 6.70″×1.32″	36.	35,200	60,400	2′3.4″	19	20 per cent. silky, balance granular (broke in bar).
15	8″×1⅝″	"	"	12.89 sq. in. 7.96″×1.62″	5.88 sq. in. 6.00″×0.98″	55.1	36,000	58,200	2′8.0″	22	75 per cent. silky, balance granular.
16	8″×1½″	"	"	11.86 sq. in. 7.96″×1.49′	5.69 sq. in. 6.18″×0.92″	52.1	34,600	58,300	2′4.4″	20	90 per cent. silky, broke 28½″ from back of pinhole.
17	8″×⅞″	"	"	6.85 sq. in. 7.96″×0.86″	3.5 sq. in. 6.48″×0.54″	49.	39,300	62,500	2′1.9″	18	Silky throughout (broke in bar).
18	8″×1¾″	29′8.9″	"	13.77 sq. in. 7.96″×1.73″	7.14 sq. in. 6.10″×1.17″	48.8	33,700	59,800	in 26 ft. 3″10.5″	15	60 per cent. silky, balance granular.

TESTS OF RE-ANNEALED 8" × 1⅞" BARS.

19	8"×1⅞"	15'6.3"	5⅞"	15.06 sq. in. 7.97"×1.89"	8.61 sq. in. 6.38"×1.35"	42.8	33,900	57,800	1'10.6"	15.7	40 per cent. silky, 60 per cent. granular (broke in bar).
20	8"×1⅞"	"	"	14.79 sq. in. 7.95"×1.86"	7.72 sq. in. 6.13"×1.26"	47.8	32,800	56,500	2'1.9"	18	40 per cent. silky, 60 per cent. granular.
21	8"×1⅞"	"	"	14.87 sq. in. 7.95"×1.87"	....	......	33,900	56,400	1'7.1"	13.2	Broke in head after pinhole had stretched to a length of 8⅜".
22	8"×1⅞"	"	"	14.77 sq. in. 7.94"×1.86"	7.98 sq. in. 6.14"×1.30"	44.6	33,300	54,600	2'0.3"	16.9	50 per cent. silky, balance granular (broke in bar).
23	8"×1⅞"	"	"	14.85 sq. in. 7.94"×1.87"	7.14 sq. in. 6.05"×1.18"	51.9	34,000	61,700	2'1.2"	17.5	85 per cent. ragged silky, 15 per cent. granular.

NOTE.—Where the fracture was partly silky, partly granular, the latter portion was always at both ends (as per figure).
Bessemer steel from Carnegie, Phipps & Co., Homestead, Pa.
Heads made at Edge Moor Iron Works, Wilmington, Del.

In speaking of steel it is hardly necessary to say that "mild steel" is meant, nor will it probably be disputed that the milder the steel (carbon between $\frac{1}{10}$ and $\frac{2}{10}$ of one per cent.), the more uniformly good the result. The superiority of steel eye-bar heads, which is proved by the results of tests made so far, is to be accounted for by the homogeneousness of the metal; all the doubts about a uniform thorough welding into one fibrous mass, which are so well founded in the case of the iron eye-bar head, are at once removed, and it is in reliance on this difference in favor of steel that the manufacturers, following the example set by the Edge Moor Iron Company, have begun to reduce the size of the steel eye-bar head. It appears now that the investigations and experiments on the best shapes of eye-bar heads, extended through so many years, have had their cause solely in the bad results of unsufficient welding, and that in substituting steel for iron, we are justified at once in using smaller heads.

The engineer who builds bridges and who, as is often the case, has no chance to visit some of the principal mills and shops of the country more than once or twice a year, may get bewildered if he considers his responsibility in view of all the requirements for good eye-bars, but the way for him is very simple. He has to insist on full size tests of a sufficient number of finished bars, thus demanding the results from the manufacturer, who has to assume all responsibility for the success of his work, which, of course, implies that the selection of the material, the mode of manufacture, and the shape of the heads, have to be left to his discretion also.

I wish to add here the results of full-size tests of steel eye-bars, made last year on the 1,200,000 pounds hydraulic testing machine of the Union

Bridge Company, at Athens, Pa., for the Grand avenue viaduct, now nearing its completion in this city. The steel for these bars is Bessemer steel from the Carnegie, Phipps & Co. mills, Homestead, Pa. The requirements for the specimen tests were: elastic limit, 32,000 pounds per square inch; ultimate strength, 62,000–70,000 pounds; minimum elongation, 18 per cent., and the specimens ($\frac{3}{4}$-inch round) to bend 180 around their own diameter, without showing crack or flaw.

The record kept at the mill of the chemical tests of each blow shows the amount of carbon to vary from $\frac{13}{100}$ to $\frac{16}{100}$ of one per cent , and that of phosphorus from $\frac{3}{100}$ to $\frac{6}{100}$ of one per cent. The eyes were made at the Edge Moor Iron Works, Wilmington, Del., with an excess of material across the eye over the bar of 40 per cent. The unsatisfactory tests, Nos. 1 and 7 of the 8 by $1\frac{7}{8}$-inch bars, caused a re-annealing of this size of bars, with results as shown (No. 19 to No. 23).

THE QUAKER BRIDGE DAM.

By Wm. A. Pike, Member of the Minneapolis Society of Civil Engineers

[Read January 2, 1889.]

Finding so much that is interesting and instructive in the reports and discussion of the Quaker Bridge Dam, I believe that a review of the same will be of interest to the Society. I claim nothing original in this paper, but simply hope to present this remarkable project in concise form, so that those who have not had time or opportunity to study the complete reports may form an intelligent idea of the reasons which have determined the special features of the scheme. As I have myself got so many new ideas as to the action of curved dams, so I hope to perhaps make the matter a little clearer to some others.

The Quaker Bridge Dam, as is well known, is a structure proposed to be built across the valley of the Croton River about two miles above its mouth, the object being to procure a water supply for New York City.

This proposed dam is to be higher by 100 feet than any other dam in the world, being from top of parapet to bottom of foundation 277 feet, or 265 to the top of the rock on which it is to be built, the rock being cut out for a depth of 12 feet. It, as first proposed, was equaled in length by only one, the Vyrnwy Dam, now under construction for the purpose of supplying the city of Liverpool with water, both dams being 1,350 feet in length. The latest plan, however, as proposed by the Board of Experts, would lengthen the Quaker Bridge Dam to over 1,400 feet.

The points principally and necessarily to be decided upon were: 1st, shall the dam be straight or curved in plan? and 2d, what form its profile should have? I may say that, when my attention was first called to the subject, my thought at once was that of course a curved dam will be stronger than a straight one, for is not an arch of a certain thickness and span stronger than a plate band or horizontal beam of the same thickness, and is not a curved dam an arch with a vertical axis? When, however, we consider that a curved dam must first act as a gravity dam, or, in other words, exhaust the effect of its

own weight in preventing its yielding to the pressure of the water before it can yield sufficiently to bring out abutment reactions, we are obliged to admit that the cases are not parallel.

Mr. Church, Chief Engineer of the Board of Aqueduct Commissioners, and Mr. Fteley, Consulting Engineer, either near the close of 1887 or early in 1888, made reports to the Board in which they recommended a straight dam and also presented a profile for the same. Chief Engineer Church gives the following reasons (not, however, in these words) for deciding on a straight dam :

1st. If a dam be of the required cross-section to resist the pressure of the water by its own weight, it cannot act as an arch. This is without doubt true if it is an absolutely rigid structure, for the dam is not forced against its abutments by its own weight as in a vertical arch, and, therefore, must move, more or less, under the pressure of the water in order to cause any arch action. It is, however, I believe, an admitted fact that no structure *is* absolutely rigid, but that even the most massive yields to some extent, however slight, to any load.

2d. If the cross-section of the dam be so reduced that it will yield sufficiently to call out arch action, then the pressure on the abutments will be too great. Thus, if the thickness of arch ring be reduced to one 100 feet or to 80 feet, the pressure on voussoir joints will be 39 tons per square foot and 42 tons for the two cases supposed, either of which pressures are far beyond a safe limit.

3d. If the cross-section be increased so that the stress resulting from arch action is within safe limits it will be more than double in area that required for a gravity dam, and then it will, as shown in the first reason, not be called on to act as an arch after all.

4th. Mr. Church develops a formula which is readily demonstrated, for the thrust at the springing of a curved dam acting as an arch which is $P = \frac{WR}{C}$ in which W = weight of water, R = radius of dam, and C = length of chord. Now, taking the same area of profile as is required for a gravity dam, and limiting the stress to sixteen tons per square foot, he finds that a radius of only 316.8 feet is allowable. A half circle of this radius would reach less than half way across the proposed dam, which renders this solution impossible.

5th. Mr. Church also gives as a reason for not depending on arch action that, as is undoubtedly true, the vertical joints in masonry are not as well filled or as strong as the horizontal ones, and hence cannot be depended on to transmit pressures as well.

These are Mr. Church's reasons for selecting a straight dam, and as far as a curved dam acting *wholly* as an arch they appear conclusive.

It is a fact, however, that many of the great dams of the world are curved, thirteen out of twenty-three cited by Messrs. Church & Fteley being of this class. This being the case, it might be supposed that there are reasons for making them curved, and that there are arguments in favor of curved dams will appear later.

Mr. Church then takes up the form of profile in an interesting and instructive way. He starts by determining a triangular section, of which the resistance to overturning is just equal to the tendency of the press-

ure of the water to overturn the dam; next he introduces a factor of safety of two; that is, designs a triangular dam that would take just twice the actual pressure to overturn it. Then, having decided to limit the pressure at any section to 16 tons per square foot, he finds that below 205 feet the profile must curve out from the straight side of the triangle. He also adds some additional material to resist strains that may arise from wind and ice, also adding still more on each toe to resist the weight of gravel and water resting on them. Finally, he adds a roadway on the top, and therefore feels justified in taking something off from the triangular section at about 77 feet from the top, thus producing the profile recommended. Mr. Fteley, in his report as consulting engineer, goes over the same ground, though much more in detail, giving complete calculations, stating that the profile was determined by observing the three following conditions:

1st. That the resultant of the forces (weight of dam and pressure of water) shall always fall within the middle third of any section, whether the reservoir be full or empty.

2d. The pressure on the masonry at any point must not exceed a certain safe limit, 16 tons per square foot being the amount decided upon.

3d. That there shall be no tendency for the masonry to slide at any joint.

The first two conditions are based on the supposition that the stress on any joint varies uniformly from one toe to the other, which can only be absolutely true if the structure is rigid, a condition which can never be completely fulfilled. As, however, the error of this assumption is on the safe side, and as the real law of the distribution is not known, it was thought best to design the dam as if the stresses were thus distributed.

The stress allowed, 16 tons per square foot, is large, but, considering the above facts and the known data as to the stone to be used, the engineers did not consider it excessive.

Soon after these reports were presented articles discussing them began to appear inthe various engineering periodicals, and in most cases curved dams were advocated and also the profile recommended was severely criticised. The *Engineering News* discussed the matter editorially and presented the following arguments in favor of curved dams. Admitting that as long as the dam could resist the water pressure by gravity without yielding, arch action could not occur, yet in case the pressure against the dam should by reason of ice, wind, earthquakes or any other cause be increased, then the ability of the dam to act as an arch would be an additional safeguard. An engineer of Philadelphia, Mr. Marechal, argued in the same way, showing that with a radius of 900 feet the pressure against the dam could be doubled before the same pressure, 16 tons per square foot, would be called out at the abutments as is allowed on horizontal joints, assuming that the dam yielded sufficiently to act at the same time by gravity and as an arch.

The principal objection to the profile presented was the weakness at the point about 77 feet below the top before referred to. It was claimed that it would have been better to have departed from the theoretical profile at a point further down, if at all, as it is near the top that the dam is likely to be affected by wind, ice, waves, etc. The broken lines of the profile were also objected to on the ground of architectural effect.

The *Engineering News* also argued that, independent of arch action, a curved dam would be stronger than a straight one, as the lateral pressures would give increased strength to the masonry, just as a specimen in a testing-machine would be stronger if subjected to lateral pressures as well as vertical than if to vertical alone. Also, that these lateral components would be balanced by a strut action through the dam at right angles to the axis, leaving only the component parallel to the axis to be resisted by the structure as a gravity dam. To this Prof. Church, of Cornell University, objected that this so-called strut action could only be called out by yielding of the masonry, and that therefore it would not be more likely to act in that way than as an arch. The *Engineering News* held that the dam would be practically a monolithic structure, leaving little or no "slack" to take up.

Whether there is anything in this strut action or not, it is I think evident that the *additional* stability that may be relied on if that of gravity be insufficient, is a strong point in favor of the curved dam. Some time after the reports of Engineers Church and Fteley were presented a Board of Experts was appointed by the Aqueduct Commission to consider the plans and report any changes they might consider advisable. As the result of their labors they recommend a change of location, a curved dam, and a modified profile.

The change of location was made for topographical reasons, and while the length of the dam is increased considerably, the amount of masonry, and hence the cost, are very little more than that of any other location proposed.

A curved dam is recommended because, while it is granted that, as long as the masonry is intact, and I may add, does not yield, no arch action will be called out, yet if for any reason the dam is not strong enough to resist the pressure entirely by its weight, the curved dam would then act as an arch and greater safety assured.

It is also to guard against indeterminate stresses from wind, ice, etc., that the curved form is preferred. This argument holds particularly well for the upper part of the dam, where such stresses will be specially felt, and where abutment stresses will be less severe than farther down, as the material added for roadway will reduce their intensity. The curved dam is also better from an architectural view, being much more effective than a straight structure would be.

The profile recommended by the Board is based on the following conditions:

(*a*) The co-efficient against overturning shall in no place be less than two.

(*b*) That the ratio of the weight of the masonry above any horizontal section to the maximum force tending to prevent sliding shall never be less than three to two.

(*c*) That the maximum stress on down stream end of joints at the river bed shall not exceed 10 tons per square foot.

(*d*) That below the river bed, on account of the lateral pressures of the earth, the pressure may amount to 14 tons per foot.

(*e*) On the upstream end of joints, when the dam is empty, the pressures may be somewhat greater, as they will be reduced as the reservoir

fills. The result of imposing these conditions is a profile with a curved front instead of one made up of broken lines, as first recommended, also with considerable greater thickness near the top, especially at the point to which attention was called earlier in this paper.

This final design appears to be an admirable one, and it is to be hoped that it may be carried out, though just at present the outcome appears doubtful. It is a great undertaking, and of course should receive the most thorough consideration before it is carried out, but I know of no example of municipal engineering that has been more carefully studied than this one, and hope to see it carried to completion.

SMOKE PREVENTION.

By Robert Moore, Member of the Engineers' Club of St. Louis.

[Read November 21, 1888.]

Of the various nuisances growing out of the conditions of modern city life the pollution of the atmosphere by smoke is one of the most persistent and hitherto the most intractable. Of modern city life, I say, for the reason that as compared with those of to-day the cities of the past were smokeless, our present condition being due to causes of quite recent origin. The great cause, of course, is the enormous increase in the use of coal as fuel which has taken place in the last fifty or sixty years, which increase, again, is due to the development of the railroad and other improved methods of transportation and to the vastly increased use of steam.

In proof of the great importance of this last-named agent as a provoking cause of the smoke nuisance we may note the fact that even in St. Louis, which is not pre-eminent in manufactures, not over one-third of the coal brought into the city is used for domestic purposes, whilst the other two-thirds are used almost wholly in the production of steam. The conditions of household fires, as compared with other fires, are, moreover, such as to limit the production of smoke, so that if this were the only use of coal the smoke even in the largest cities would not be a very serious matter. The dense black clouds which now pour their polluted breath over everything, and at times shut out the light of day, are from fires which have their sole origin in the use of steam; so that smoke in the sense which concerns us now is a product of the present century and one of the outgrowths of the genius of James Watt.

But before there can be any useful discussion of means for the abatement of this nuisance, and the practicability of their adoption in our own city, it is necessary to get definite ideas as to the exact nature of smoke and the conditions which determine its production.

Visible smoke, then, for we have no concern just now with the invisible products of combustion, is carbon in a finely divided state which escapes from the fire in which the remainder is consumed. Owing to the fineness of the particles its coloring power is very great, and the absolute quantity of carbon in even the blackest smoke is very small. On this point the common opinion, which places the amount of fuel lost in the smoke at high figures, is wholly at fault. To determine the exact

amount of carbon in smoke, Mr. J. C. Hoadley, of Boston, several years ago (August, 1881), by means of a suction fan which drew the products of combustion through a vat of water in which was placed an intercepting screen of cotton cloth, collected for one week all the soot from the flue of a steam boiler "fired with bituminous coal and producing very black smoke," and found it to amount to but one six-hundredth part of the coal burned, or one grain for every 29 cubic feet of the escaping gases.*

To demonstrate to the eye the very great coloring power of carbon in the form of soot, Mr. C. F. White, of Washington University, has very kindly repeated for me an experiment suggested many years ago by Mr. C. Wye Williams by putting into a bottle of clear water an amount of soot equal to one part by weight to 2,666 parts of water. From the deep black color which it produces you can understand how the dense and solid-looking clouds which at times issue from our large chimneys may, after all, contain but a very small percentage of carbon.

From this view of the matter we at once reach a conclusion of prime importance in any discussion of smoke prevention, and that is, that it has no special pecuniary importance to the coal user. He has, in fact, very little interest in the matter beyond that which he shares with the public at large. But whilst the loss to the coal user is very small, the injury to the community is very great. The damage by soot to goods, furniture, books and pictures, and the additional costs of housekeeping, would, if they could be computed, be found to be a very large sum. For the city of London a recent estimate by Mr. A. F. Russell places it at five millions pounds sterling per annum. The damage to health also is very considerable. In the same paper to which I have just referred Mr. Russell makes the statement that in the great fogs of 1880 in London, the effects of which are always greatly intensified by the smoke, the death rate rose from 27.1 per 1,000 for the week ending January 24 to 48.1 for the week ending February 7, which was the period of thickest fog. In three weeks, from January 24 to February 14, the excess of deaths over the average in London was 2,994. The cases of illness due to the same causes were probably ten times this number. Mr. Russell also notes that in the week ending February 7 the deaths from whooping cough were 248, a number beyond all precedent, and that the deaths from bronchitis were 1223.†

In addition to which, motives of no less cogency for the prevention of smoke may be found in the lowering of the standard of cleanliness, in the defacement of the landscape, and the general discomfort and depression of spirits which the murky atmosphere produces. It is, indeed, one

*_American Machinist_, Dec. 23, 1883. See also Report of the Smoke Abatement Committee of 1882, published by Smith & Elder, London, 1882, page 40.

† See "Nature" for November 8, 1888. Prof. Chandler Roberts (_Popular Science Monthly_, November, 1888, page 139) by a different method of reasoning places the cost of smoke in London at £4,600,000, or about one pound sterling per year for each inhabitant, which agrees very well with Mr. Russell's figures. Calling the population of St. Louis 450,000, this rate would give an annual loss of $2,250,000. Of course no figures on this subject can pretend to be exact, but they have some value as indicating roughly what is beyond all question a serious pecuniary loss.

of the greatest deductions from the pleasure of life in cities, and in this city its banishment would add more to the comfort of living and to the value of residence property than any other single thing whatever. And when we consider how closely cleanliness is allied to godliness, how largely civilization consists in the removal of the dirt and the suppression of the nuisances which characterize the savage life, and the fact that its power to purchase comfort is that which gives to money its value, the subject takes on a higher aspect and becomes one of the first importance.

To locate definitely the origin of smoke, which is the first step in any study of the means for its prevention, it is necessary to subject the coal from which it proceeds to an analysis, of which the first and most important steps are extremely simple and can be taken by any one.

If the bowl of a common tobacco pipe, which has first been filled with soft coal broken to a fine powder and then covered over with clay, be placed over a fire we shall in a few minutes find issuing from the stem a stream of gas which, if lighted, will burn with a bright flame. This is identical with the ordinary illuminating gas, except that the latter before distribution is passed through various purifying processes for the removal of the sulphur and ammonia.

Recurring to our experiment we find the flow of gas presently ceases and the flame goes out. On removing the covering of clay we find the powdered coal has been fused into a single porous mass of what is known as coke, which is composed mainly of pure carbon. The coal meantime has lost in weight from 30 to 40 per cent. If now we continue the experiment still further by subjecting the coke to a sufficient heat, we shall find that whilst there is no flame and no smoke the whole mass will become incandescent, with a large evolution of heat, until finally the fire dies out, and there is nothing left but a small residue of whitish incombustible matter known as ash. The weight of this residue varies with the quality of the coal from 6 to 20 per cent. of the original mass.

Here, then, we have found the three constituents of all soft coal: First, the volatile combustible matter or gas; second, the fixed carbon or coke; and third, the incombustible matter or ash.

Now, in the burning of the coke, as we have already observed, there is neither flame nor smoke, so that in searching for the origin of smoke this element of the coal as well as the ash may be set aside and our attention confined wholly to the first, or gaseous element. Upon subjecting this part of the coal to analysis by the more refined methods of the chemical laboratory, it is found to be of a somwhat complex nature, but to consist essentially of various combinations of the two elements, hydrogen and carbon. Now whilst each of these elements combines with oxygen in the process known as combustion, neither of them when burned by itself produces any smoke. The hydrogen flame is smokeless, and so also is a fire of coke or charcoal, both of which are fuels in which the only combustible matter is carbon. Smoke is evolved only from a fuel containing both hydrogen and carbon in combination, such as the coal gases, which we now have under consideration. The reason for the appearance of this phenomenon in this case is found in the fact that of

the two elements composing the gas, the hydrogen has an attraction for oxygen much greater than that of the carbon. That is to say, the hydrogen burns more readily than does the carbon. When, therefore, a complex molecule like those of coal gas is brought into contact with a portion of oxygen which is not sufficient in quantity for the combustion of both of its elements, the hydrogen seizes upon the supply first and thus sets the carbon free, when it assumes the form of the black precipitate known as soot or smoke. Or again, if with an ample supply of oxygen the temperature be for any reason below the kindling point of carbon, which is considerably higher than that of hydrogen, the latter only will be burned and the carbon set free as before.

In the absence of hydrogen, and with a fuel composed of carbon only the results of the foregoing conditions are wholly different. With too low a temperature there is no combustion at all and the fuel remains unchanged. If, on the other hand, the temperature be high enough but the supply of oxygen too small, there may be either a complete combustion of a part only of the fuel or a partial combustion of the whole. In the former case part will be unchanged and a part converted into carbonic acid (CO_2), an invisible gas, and in the latter the whole will be converted into carbonic oxide (CO) also an invisible gas. In neither case is any carbon set free in the form of visible smoke.

This, then, is the theory of the production of smoke. It is the result of the combustion of the hydrogen only in a hydro-carbon fuel and the consequent precipitation of the carbon, which result may be due either to a temperature too low to ignite the carbon or to an insufficient supply of oxygen.

Having thus reached definite ideas as to the nature and origin of smoke, we are now prepared to discuss intelligently the means for its prevention. But before proceeding to consider these in detail, we may note that every plan for the abatement of the smoke nuisance must be embraced in one of two great classes, to wit :

First.—The class of methods which involve the use of smokeless fuels, and

Second.—The class of those which do not involve the abandonment of the smoke-producing fuels, but propose means for using them in such manner that the smoke shall be prevented.

Taking up these two classes of remedial measures in order, we see from what has gone before that as smoke is due to the imperfect combustion of a hydro-carbon fuel, it may be avoided by the use of fuels without hydrogen. The fuels of this class are three: anthracite, coke and charcoal; and the general use of either of them would be a complete solution of the problem which we have in hand.

The difficulty, however, with each of these is that its cost is so great as to place it for us here practically out of reach, except for uses of a very limited and special character.

That this is true of charcoal goes without saying. Even wood, which is much less expensive, has, in the progress of time, disappeared from use as fuel except in remote districts and for strictly domestic purposes. Until a few years ago charcoal has had a very limited use in the kitchen and laundry, but the cheaper and more convenient gas stove has now

routed it even from these its last refuges, and we may consider it now as a thing of the pas .

With the other two fuels of this class. anthracite and coke, the case is somewhat different. Of both these the statistics gathered by the St. Louis Merchants' Exchange show a large and increasing use. amounting in 1887 to 65,000 tons of anthracite and 167,726 tons of coke. Both, however, are small when compared with the 2,661,000 tons of soft coal used in the same year. Or, reducing these figures to percentages, we find that of the total fuel used in St. Louis in 1887 :

92	per cent.	was soft coal,
$5\frac{3}{4}$	"	" coke, and
$2\frac{1}{4}$	"	" anthracite.

And when we look a little closer into the matter the reasons for these figures become very evident. For when we take the average ruling prices of each class of fuel and combine them with the figures expressing their actual value for steam purposes, we find that to evaporate 1,000 pounds of water will cost—

With soft coal ($7\frac{1}{2}$ cents per bushel),	15 cents.	
" coke ($4.60 per ton) "	33 "	and
" anthracite ($7 per ton), "	40 "	

Nor is there any probability of anything in the future that will change the order or relative value of these figures. The cost of the coking process and the necessary waste which it involves, our distance from the anthracite field and the increasing drafts which are being made upon it by consumers nearer at hand, will always make these two fuels expensive for all purposes where heat alone is required. So that for all except special uses in which mere heating value is of subordinate consequence, such as the use of coke for melting iron, and the use of anthracite for warming houses, these two fuels are, as regards St. Louis, effectually ruled out.

Still another class of smokeless fuels are those which contain hydrogen but contain no solid carbon, a class of which the two principal representatives, to wit: petroleum and fuel gas, are of very great and constantly increasing importance.

It will be observed that I have called these smokeless fuels, notwithstanding the fact that they are both hydro carbons and both capable of producing unlimited smoke. Yet, owing to the absence of solid carbon and their consequent homogenity of structure, the requirements of the air supply in burning them are always the same. The mechanical adjustments necessary to insure perfect combustion are. therefore, so easy to make and to maintain that both these fuels are in fact burned without smoke.

By far the more desirable of these two is the fuel gas. The ease with which it is transported and controlled, the almost unlimited uses to which it can be applied, from the warming of a bed chamber to the melting of the most refractory metals and the entire absence of smoke or dirt of any kind in its use, all make it the ideal fuel, and give color to the belief that this was the fire stolen by Prometheus from the gods. No marvel in all fiction is greater than the transformation which this agency has wrought before our eyes in the smoke-buried city of Pittsburgh, nor

do we wonder that a spring of this kind on the shores of the Caspian should have been, as for centuries it was, the most sacred shrine of the Fire Worshipers.

When, however, we come to weigh the probabilities of the like transformation for St. Louis, we are met by the unwelcome facts that there is probably no adequate supply of natural gas within our reach, and that no form of artificial gas has yet been found to take its place. It is true that for metallurgical works in which a very high and uniform temperature is required, gas made in the ordinary open-air producer has to a very large extent taken the place of coal. This gas, however, which consists essentially of hydrogen and carbonic oxide, due to the partial combustion of the coal is so highly diluted with inert nitrogen from the air (from 50 to 70 per cent. of the whole volume) that it will not bear transportation in pipes, and the plant for making it on the premises is too cumbrous and expensive for use except in large and important works.* As for the richer gases, made by either the common retort or the water gas system, they are, and will probably continue to be, too expensive ever to take the place of coal except for very limited and special uses. To evaporate 1,000 pounds of water, for example, by means of common illuminating gas, at $1.50 per 1,000 cubic feet will cost $2.25, whereas with our common soft coal the same work can be done for 15 cents. And when we reflect upon the fact that in order to compete on equal terms with soft coal for ordinary heating and steam purposes, gas of calorific power equal to the common illuminating gas must be made and distributed for 10 cents per 1,000 cubic feet, the prospect for its general use as fuel becomes so remote that for all present purposes it may be dismissed.

Far better than for gas is the outlook for petroleum. In consequence of the opening of new oil fields and improved methods of transportation, the price of petroleum has within the last few years been much reduced, and its use as fuel widely extended. Its high calorific power, the ease with which the flame can be regulated, and the entire absence of ashes or smoke give it a rank as a fuel second only to gas. Its largest use for this purpose is in southeastern Russia. On the steamers which ply on the Caspian and the Volga, and on some of the railroads, notably the Grazi-Tsaritsin Railway, it is the only fuel used. Of the satisfaction which there attends its use, a recent traveler, Dr. Chas. B. Dudley, of the Pennsylvania Railroad, speaks in the strongest terms. "The comfort to the passengers," he says, "by the use of this magnificent combustible for generating steam can hardly be described. Not a cinder or a trace of smoke ever disturbs them. Windows can be left wide open so far as the locomotive is concerned." In this country its use has been so far limited to points in the immediate vicinity of the oil regions or to points remote from coal, like Minneapolis or New Orleans, where the facility of transportation is so much in favor of petroleum that it is beginning to displace coal. In St. Paul, where it is now used in the power house of the cable railway, it is reported to be equal in cost to coal at $3 per ton.

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* Some recent experiments in St. Louis gave reason for hoping that by modifying somewhat the form of the producer, and placing it close to the boiler, gas can be made and used economically for producing steam even in plants of moderate size.

Even in Chicago, where coal is cheaper, the recently completed pipe line from the Ohio oil field will no doubt give rise to a very large use of petroleum as fuel.

There are, however, two serious drawbacks to its general use in cities; the first of which is the fact that in the judgment of insurance companies, it increases the risk of fire; and the second, that the crude oil, which is the only kind available for fuel in this country, has a smell so pungent and penetrating that in a crowded neighborhood it would probably be a greater nuisance than the smoke. Added to which there is here in St. Louis the further fact that for equal quantities of heat its cost is as yet considerably greater than coal. As the result of a working test extending over a number of days, made in June last at the Washington University, the cost of evaporating 1,000 pounds of water was found to be 24 cents, or 60 per cent. more than the cost of doing the same work with soft coal. These figures, which tally very closely with the results obtained in Minneapolis and St. Paul, are, however, much below those for any of the other fuels we have considered, and give to petroleum in point of cost a rank next only to our ordinary coal. For special uses it is no doubt economical even now, and its cost may perhaps be stll further reduced. To equal soft coal, however, it will have to be delivered to consumers here at a cost not exceeding $1\frac{6}{10}$ cents per gallon, or 65 cents per barrel, figures which are far from being in sight now.

Here, then, as a result of our inquiry, we find ourselves face to face with the conclusion that for St. Louis there is no prospect of relief in a change of fuel, but that, for all ordinary every-day uses, the fuel with which nature has here so bountifully provided us must be accepted "for better or for worse," and the problem of smoke prevention worked out upon the basis of the continued use of our common, raw, bituminous coal.

Addressing ourselves, therefore, to this problem we note first of all that inasmuch as all the smoke produced in the burning of soft coal arises from the gas, the real problem is still further narrowed down to finding means for the perfect combustion of the coal gas in the same furnace in which the fixed carbon is also burned. It is from this mixture of the two kinds of fuel, gaseous and solid, that the whole difficulty of the problem arises. With gas alone it is a perfectly simple matter to so arrange the air supply that the combustion shall be smokeless, and with coke alone smoke is impossible; but to completely burn the two at the same time and in the same furnace has proven in practice to be a problem of the first magnitude.

The reason for this difficulty is not far to seek. To burn the fixed carbon, in which the greater part of the heating power of the coal resides, the air which furnishes the oxygen should be introduced from below so as to pass up through the incandescent mass. If introduced above the fire it is at once heated and struggles to get away. If burning coke alone, we shut off all openings above the fire as not only useless but hurtful, for the reason that the introduction of air at this point tends to fill the partial vacuum by which the air is drawn through the fire from below. But under the actual conditions we have along with the coke, and rising from it, a large volume of combustible gas, to burn which a corresponding volume of air must be introduced into the upper part of the furnace

above the bed of incandescent coke. It is here the gas is found, and here, if at all, it must be burned.

Here, then, we have the conflict. To burn the coke we should admit air only from below, whilst to burn the gas we must admit air into the upper part of the furnace, and to that extent check the combustion of the fixed carbon, in which the heating value of the coal mainly resides and upon which the evolution of the gas itself depends.

As in many other conflicts, the solution is a compromise. To burn the coke and make a heated bed, on which to distill the gases from the fresh coal, the greater part of the air must be admitted through the grate bars, but another and considerable part (from 15 to 20 per cent.) must, for the prevention of smoke, be at the same time admitted above the bed of burning coal. All this, however, could be arranged, and the amounts and points of admission of the air supply adjusted to the requirements of the two kinds of fuel, were these requirements only known and constant. But, as a matter of fact, and under the ordinary methods of firing they are extremely inconstant, and can hardly be exactly known at any single instant. When fresh coal is thrown on the fire there are a few minutes in which the evolution of gas, and the consequent demand for air to consume it, is very large. This evolution of gas, however, soon ceases when there is left a fire of the fixed carbon only for which the requirements of the air supply are entirely different. Unless, therefore, the evolution of gas can be kept constant, which with a furnace fed intermittently in the ordinary manner is practically impossible, the only way to insure complete combustion at all times, and the resulting absence of smoke, is to vary the amount and source of the air supply so as to correspond with the ever-varying conditions of the fuel. But to do this successfully is a task calling for a degree of watchfulness, industry and skill far beyond the resources of the ordinary firemen. And when in view of these difficulties we recall the fact that the amount of fuel lost in the smoke is after all so trifling, the inky clouds which issue from our chimneys cease to be a matter for wonder.

Coming now to the means by which these results may be prevented, we find that the more meritorious devices, which alone we need consider now, may be grouped into two principal classes, of which one aims to regulate the supply of coal to the fire, whilst the other seeks to regulate the supply of air.

The first class is that of the so called "mechanical stokers," the aim of all which is to secure a uniform evolution of gas by means of a constant supply of coal, fed to the fire by suitable mechanism. Of these there are a large number, as specimens of which in this country may be mentioned the Brightman, Hodgkinson and Roney mechanical stokers, and the Murphy "smokeless furnace." Though differing in many respects, these are all alike in feeding the coal regularly to the fire by mechanical means without opening the furnace door. Some of them, as the Brightman and the Roney, have also means for removing the masses of molten ash or clinkers. With the coals burned here, this is a matter of much importance, as they all contain a large quantity of very fusible ash, and the want of means for its easy removal when formed into clinkers is a serious defect.

One very important feature of this class of furnaces is that they all require the coal to be broken to nut size before it is used. As the air passes less readily through the coal when fine than when it is in larger lumps, this requirement interferes with the burning of coal in large quantities and accounts in great measure for the slow rate of combustion which, so far as I can learn, characterizes all furnaces of this kind. The general idea, however, which lies at the bottom of this class of devices, viz.: That the coal should be fed to the fire at a uniform rate and without the cooling effect due to opening the furnace door, is entirely sound, and in practice some of them give most excellent results in the economical production of steam and the prevention of smoke. Within certain limits as to the rate of combustion, which are unfortunately rather low, they are fairly successful solutions of the problem in hand.

A second class of smoke-preventing devices is one which leaves the present method of firing unchanged, but provides special means for the introduction of air above the fire and its thorough intermixture with the coal gases.

One of the first of these, whose name now is legion, is the so-called Argand furnace, patented in 1839 by Mr. Chas. Wye Williams, of Liverpool, who was one of the first to firmly grasp and clearly state the true conditions of the combustion of coal and the prevention of smoke, and who wrote a treatise thereon which is still the beginning of wisdom for all students of this subject. His furnace, which was an adaptation of the principles of the Argand gas burner to the combustion of the furnace gases, consisted essentially in the introduction of air above the coke bed through a number of small orifices from three-eighths to three-quarters of an inch in diameter, the point of introduction being sometimes in front, sometimes at the rear, and sometimes at the sides of the furnace. This furnace at once attained a marked success, and the general ideas embodied in it have since then been the basis of a multitude of similar devices, some of which (the Jarvis furnace for example) are almost identical with the Argand furnace of Wye Williams.

Of course the efficiency of any arrangement for the admission of air is increased by increasing the draft, which may be done either by adding to the height of the chimney or by mechanical means. The value of the latter method was fully recognized by Williams, who gives in his book (pages 134–138) an account of some very successful French experiments in which the draft was produced by means of a suction fan in the furnace stack. Still another and later method of increasing the velocity of the air supply is the use for this purpose of an air injector actuated by a jet of steam.

In this class of devices, of which there are quite a number, small openings are made into the furnace above the coal precisely as in the Argand furnace of Wye Williams. But instead of depending upon natural draft to force the air through them, there is in each a small jet of steam, which projects the air into the fire with a high velocity and causes the mixture of hot air and gas to be made more quickly and thoroughly than is practicable by natural draft alone. The result of this where the number and arrangement of jets is properly made is a very perfect combustion of gas with an almost entire absence of smoke. Two devices of this kind

are now in actual use in this city. One of them may be seen at the power house of the Olive Street Cable Railway, and the other at the store of D. Crawford & Co.

In principle this method of smoke prevention is entirely sound, and the results actually attained are very good. It has also the great merit of being comparatively inexpensive, and of being easily applied to an existing furnace. In these respects it has greatly the advantage over the class of mechanical stokers, which are much more costly, and can, as a rule, be applied to an existing plant only by entire re-construction of the furnace. It has also the further and very important advantage of admitting a higher rate of combustion than so far seems practicable by the other method, thus giving to the same set of boilers a greater working value.

This reduction of capacity has up to this time been the greatest obstacle of all to the introduction of smoke-preventing furnaces. A very careful and very valuable series of tests of the actual working of such furnaces has been made by Professors White, Jones, Potter and Johnson, of the Washington University, who have thereby done more than any other persons whom I know to convert the ordinary crude guesses upon this subject into exact and scientific knowledge. Their experiments, which have included the Backus, the Hall, the Jarvis, the Williams and the Murphy furnaces, have shown that by their use in such a manner as to be smokeless, the capacity of the steam plant as a whole is from a value of 100 per cent. given by the common smoke-producing furnace brought down to 60, a reduction of 40 per cent. In other words, if with the common furnace burning coal without any regard to the amount of smoke produced, it requires three boilers to make a given amount of steam, five boilers will be required to make the same amount of steam if a smokeless furnace be used. As our steam boiler practice here has always been largely governed by that of the river steamboats on which it is of vital importance to make the needed steam with the smallest boiler possible, and as, moreover, many steam users are unable as well as unwilling to incur the increased outlay necessary for a smokeless plant, the introduction of these has until recently made little or no progress. Many have put in smoke-burning devices, but finding they could not make the steam which their business demanded, have taken them out and reverted to the old methods, which do indeed produce smoke, but do at the same time give them the power which they require. And unless some method is found by which this difficulty can be overcome, the prevention of smoke will be seriously embarrassed, as it will in practice be found to be a matter of much difficulty to compel steam users to make the larger investment of money which a smokeless plant will require.

In order to ascertain by an actual test the performance in this respect of the device in use at the Olive street power house, which was not included in the series of tests already mentioned, Mr. P. C. Maffit, President of the Missouri Railroad Company, very kindly consented to put the plant for this purpose at the disposal of Mr. C. E. Jones, of the Manual Training School, who volunteered to give the matter the necessary time. Such a test was accordingly made on October 13, extending

from 7:30 in the morning until 11 o'clock at night. During this time the boilers were run first at the ordinary rate necessary to do their regular work, burning 23 pounds of coal per square foot of grate surface per hour; second, at a rate of 32½ pounds; third, at a rate of 27 pounds, the smoke-preventing apparatus being all this time in full operation and the amount of smoke produced being noted by an observer stationed on the roof. Finally the plant was run for three hours with the smoke burner shut off.

Whilst these experiments were not sufficient to determine all the facts in regard to the working of the apparatus, notably the amount of steam required to operate it and its effect, if any, on the boiler, they were enough to show that simply as a preventer of smoke it has much merit. Up to a rate of 27 pounds of coal per square foot of grate surface it was practically smokeless. Beyond this rate of firing there was a good deal of smoke, though very much less than with an ordinary furnace. Though in practice it is sometimes desirable, or even necessary, to push a furnace to a rate of 35 or even 40 pounds of coal per square foot of grate surface per hour, it is not common, and ought, perhaps, never to be necessary. So that a furnace which will, as in this case, burn 27 pounds substantially without smoke may be considered as fairly successful.

I am of the belief, however, that the highest success attainable will be reached by a combination of these two general methods, viz.: by some form of mechanical stoker which will feed larger coal than those now in use, coupled with means for the admission of air, by a forced draft if necessary, in proper quantity above the coal or at the bridge wall for the combustion of the gases. I do not know of any existing apparatus which quite fills this ideal, but I can see in it nothing impracticable, nothing which we may not reasonably hope to attain. On the whole, we are, I think, justified in the belief that with proper efforts the smoke nuisance can even now be very greatly mitigated, and in course of time substantially abated. To do this will no doubt cost something in money and something in convenience to the coal user. The same thing may be said, however, of nearly every other public nuisance. As a rule their abatement is attended with both trouble and expense, and hardly any of the comforts of civilization are given to us for nothing. But even if the sacrifice required in this case were much greater than it is ever likely to be, it is no more than we have a right to ask, or even to require the citizen to make to the comfort and well being of the community at large. And to help form a public sentiment which will emphasize and enforce this demand, and without which the most stringent ordinance will be a nullity, is a worthy object both for individual and associated effort.

APPENDIX.

FOR PURPOSES OF COMPARISON AND ON ACCOUNT OF THEIR PERMANENT VALUE A FEW OF THE TESTS REFERRED TO IN THE BODY OF THE PAPER ARE GIVEN BELOW.

Boiler and Furnace Tests Made at St. Louis, Mo.

	1	2	3	4	5	6	7	8	9	10	11	12	13
Place	Wash'n Univ.	Wash'n Univ.	Wash'n Univ.	Meram'c Mills.	Medart Pully Co.	Excels'r Found'y.	Hotel Beers.	Anheuser-Busch Brewery.	Anheuser-Busch Brewery.	Olive Street Power House. October 13, 1888.			
Date	Mean 8 tests.	Mean of 3 tests, June, '81.	April, '85 Mean of 3 tests.	....	....	June, '85.	....	Mean of 2 tests.	Mean of 2 tests.				
Duration	82½ hrs.	21½ hrs.	24 hrs.	9 hrs.	9 hrs.	9.5 hrs.	5 hrs.	15 hrs.	15 hrs.	7 hrs.	2 hrs.	1 hr.	3 hrs.
Kind of furnace	Common.	Williams	Backus.	Jarvis.	Murphy.	Boileau.	Wilson Annex.	Common.	Meier.	Common	Common	Common.	Common.
Grate surface, sq. ft.	24	25	25	38.25	22.5	52.5	20	41	35	48	48	48	48
Style of boiler	36, 4 in. tubes.	Same.	Same.	12, 6 in. tubes, 20.	....	2 flues.	....	....	Heine.	Hor. tubular.	Same.	Same.	Same.
Heating surface	750	750	750	1,090	705	1,080	670	1,860	1,287	1,380.5	1,380.5	1,380.5	1,380.5
Ratio of grate surface to heating surface	1 to 30	1 to 30	1 to 30	1 to 28.5	1 to 31	1 to 21	1 to 33.5	1 to 45.3	1 to 36.7	1 to 28	1 to 28	1 to 28	1 to 28
Kind of coal	....	Collinsville.	Collinsville.	Slack and Nut.	....	....	....	Bryden & Freeburg.	Bryden & Freeburg.	....	....	....	....
Amount burned in lbs.	56,600	9,900	12,000	4,781	4,950	5,932	1,150	16,200	14,700	7,637.5	3,120	1,302.5	2,542.5
Coal, per sq. ft. grate surf., per hour	28.53	18.42	20	13.86	24.4	11.89	1,150	26.34	28.0	22.73	32.5	27.11	17.60
Ash, pounds	7,132	1,336	1,555	1,228	735	708	150	1,887	1,533	....	....	....	....
Ash, percentage	12.57	13.19	13.00	25.7	14.8	11.9	14.3	11.65	10.04	....	....	....	....
Combustible, pounds	49.444	8,564	10,445	3,556	4,215	5,224	1,000	14,313	13,167	....	....	....	....
Temp. of feed water	164.6°	148.8°	169.3°	180°	197.3°	203°	175°	208°	154°	206°	206°	206°	206°
Steam pres., lbs. p. sq. in.	52.1	61.5	50.8	81	78.5	72	82	95.2	94.7	94	94	94	94
Water evaporated, lbs.	324,977	49,552	73,800	25,315	26,141	32,389	7,222	98,508	101,608	39,272	19,060	7,441.5	14,883
Water per sq. ft. heating surface, per hour	5.3	2.64	4.1	2.58	4.12	3.15	2.15	3.53	5.27	4.06	6.90	5.52	3.59
Equiv., from and at 212°	5.7	2.89	4.39	2.76	4.33	3.29	2.13	3.87	5.77	4.25	7.21	5.63	3.76
Water, per lb. of coal	5.74	5.00	6.15	5.88	5.28	5.46	6.27	6.08	6.91	5.37	6.38	5.97	6.12
Equivalent	6.18	5.48	6.59	6.29	5.54	5.71	6.73	6.67	7.58	5.75	6.67	6.09	6.41
Water, per lb. of comb'e	6.55	5.79	7.07	7.12	6.22	6.20	7.22	6.88	7.71	....	....	....	....
Equivalent	7.05	6.19	7.57	7.62	6.53	6.47	7.75	7.55	8.46	....	....	....	....
Chimney temperature	456°	....	....	426°	712°	406°	....	496°	520°	....	....	....	....
Eff'y p. lb. of coal, p. c.	51.5	....	....	52.4	46	....	....	....	....	....	....	....	....

Test No. 10, at Olive Street Power House, Hutchinson Smoke Burner in operation. Test No. 11, at Olive Street Power House, Hutchinson Smoke Burner in operation. Test No. 12, at Olive Street Power House, Hutchinson Smoke Burner in operation. Test No. 13, at Olive Street Power House, Smoke Burner off.

RECENT IMPROVEMENTS IN ELECTRICAL TRANSMISSION.

By N. S. Possons, Member Civil Engineers' Club of Cleveland.

[Read November 13, 1888.]

The great subject of electricity, that invisible force which is so engrossing and absorbing the busy minds of our youth to-day, presents a field unbounded. The uses to which this force can be put are to the scientific man and observing student of an exceptional and significant character. Perhaps I may be permitted to state that the advancement of science is to the inquiring mind more suggestive and more studied than any other field. The grand principle of electrical transmission of energy is becoming better understood. We are continually advancing; each hour makes a forward step towards success. But there are other ways of advancing and adding to the sum of human knowledge, by studying methods of construction.

The discovery of electric currents originated with Galvani, a physician in Bologna, who, about the year 1786, made an important observation upon the convulsive motions produced by the "return shock" and other electric discharges upon a frog's leg. He was led by this to the discovery that it was not necessary to use an electric machine to produce these effects, but that a similar convulsive kick was produced in the frog's leg when two dissimilar metals, iron and copper, for example, were placed with a nerve and muscle respectively, and then brought into contact with each other.

Galvani imagined this action to be due to the electricity generated by the frog itself. It was, however, proven by Volta, Professor in the University of Pavia, that the electricity arose not from the muscle or nerve, but from the contact of dissimilar metals. When two suitable metals are placed in contact with one another, one becomes positive, the other negative. This Volta proved in many ways, one of which was known as the Volta pile, and consisted in placing in contact a number of dissimilar metals so arranged as to add to their electrical effect together. These effects were more powerful in proportion to the number of their contacts.

Another combination was a number of cups filled with acidulated water into which was dipped a number of strips of copper and zinc, the copper becoming what is termed the positive pole, the zinc the negative. There will be a continuous flow of electricity from the zinc to the copper through the cells. It will also show that the zinc is slowly dissolving in the dilute acid, and that this action goes slowly on as long as the two are connected. The current itself cannot be seen to flow, hence to prove it a knowledge of some of the effects is required which a current will produce. Flowing near a magnetic needle will cause it to turn, or flowing through a thin wire will cause it to heat, or flowing through water will decompose it, or, lastly, flowing through a living body or a sensitive portion of it produces certain sensations.

The term electromotive force is employed to denote that which moves electricity from one place to another. Just as in water pipes, a difference

in level produces a pressure, so E. M. F. sets up a current just as soon as a circuit is completed for the electricity to flow through. The same E. M. F. does not always produce a current of the same strength. The strength depends not only on the force depending to drive the electricity around the circuit, but also on the resistance which it has to encounter to overcome the flow. When the wire is complete, if the circuit be very long or very slim the action will be partially stopped. I have in the foregoing explained to you the E. M. F., or, as we term it, the tension of the current, and the resistance of a circuit. This we designate the Ohm. There is still another term called the Ampère, which is the unit of quantity. With these terms we are prepared to make all our measurements in electrical science.

It is needless for us, in our limited time, to follow up the experiments of Franklin, when the wetted strings from his kite during the passing of a storm conducted the electricity to the earth and yielded an abundance of sparks, but will pass on to the early discoveries of Faraday in 1832, to whom is given the credit of discovering the principles of the dynamo machine. This great discovery remained apparently dormant until Gramme, a cabinet-maker, brought out his celebrated machine, which was to give an impetus to this new discovered force. Later on Mr. Brush brought out his wonderful series lamp, which is so extensively used. A few years later came incandescence lamps, of which I will endeavor to give a general description of one or two, avoiding all technical details, because I do not think any one present is prepared to manufacture, although some may be called upon to manage lamps supplied by the manufacturers. These various makes of lamps differ from each other in the method of preparing the carbon filament.

All incandescence lamp filaments consist of some vegetable substance which has been carbonized. The ends of these filaments are connected with two platinum wires passing through the glass, which is melted to them. Platinum is used because its expansive rate is about the same as glass, and prevents the glass from cracking in cooling.

For lighting purposes metal and carbons are the classified conductors, the resistance increasing for small diameters inversely proportional to cross section. Desiring to concentrate heat at a given point, we place a sufficiently high resistance at that point and force a strong current through it so as to make it glow and give light. In all lamps, either an indestructible resistance, or one easily or cheaply renewed, is adopted.

It would be impossible to use platinum wire, as this fuses at too low a temperature. Carbon alone satisfies in a measure the conditions. It has never been fused, hence the fine thread of carbons is brought to a high state of incandescence, and prevented from oxidation by being hermetically sealed in a glass bulb from which all the air has been exhausted. The life of the lamp depends largely upon its perfect exhaustion or the goodness of its vacuum. Sprengal mercury pumps have been modified for this object, to drive out the gases which remain when exhausted cold. Hot exhaustion is resorted to while the lamp is still attached to the pump. A current of electricity is sent through the filament, and all the gases driven out of the carbons, and the lamp sealed while the current is passing.

The form of the lamp is generally pear-shaped. The filament is a thread of cotton parchmentized by immersion in acid and water, and allowed to remain in this a sufficient time to effect the necessary change, and then thoroughly washed to remove all trace of acid. This has the effect of destroying the fibre of the cotton, so that after parchmentizing the thread becomes transparent. It is then drawn through dies to reduce to a uniform size. Carbonizing consists in burying powdered charcoal and raising to a very high temperature, allowing it to remain under this heat for several hours. The whole process of manufacture is delicate, and in most of our factories girls and young boys are employed on account of delicacy in their touch.

Mounting the lamps consists in bringing the platinum connected to the carbon out in a loop, and these are fitted with a brass ferrule or suitable connection to fit to a turn off. In the arc lamp the current is sent through two carbons which touch each other. As soon as the current is established these carbons separate, and the current continues through the heated air and vaporized carbon, which is a conductor of high resistance. Great heat is produced at the poles and the carbons glow with an intense whiteness. These detached particles of carbon are heated in the air and form a luminous arc. In incandescence lamps the resistance used to convert electricity into heat is composed of so fine a thread that it would at once be destroyed if heated in open air. In incandescence lighting the current leaves the mains and divides between them. When thus placed side by side, and the current divided between them, they are said to be in parallel system, multiple arc or in quantity. When arranged end to end they are said to be in series. Arc lamps are always run in series, while incandescence lamps are run in multiple. In many stations both arc and incandescence are run from the same circuit. To accomplish this successfully a proper device is provided to avoid accident.

We now come to the important branch of transmission.

It having been discovered that when two electro magnets were caused to attract each other, they might be excited so as to mutually repel. This was brought about by merely reversing the direction of the current in one. This led to the conception of an electro-motor, with the idea that such a machine might prove more safe and less troublesome than a steam engine for driving small power. Probably the first motor was constructed in the year 1834 by Prof. Jacobi, a Russian. Then followed various motors embodying examples of high inventive powers, ingenuity and constructive skill. These were utilized for railway purposes and the propulsion of ships.

The motors of 1848 were greatly improved over those previously invented, but they were all found too wasteful of zinc in the generators. At that date they were actuated by an electric current evolved from a battery, which converted the potential energy of zinc into an electric current. This, as compared to coal, was in proportion as seven to one in expense.

A vast amount of skill and ingenuity has been expended in almost fruitless endeavors to construct efficient electro-motors. A large proportion of former attempts upon erroneous notions regarding electricity

have been conducted by inventors possessing all the requisites save that most essential, "the success of their experiments."

The gradual growth in electrical science brought new facts to light. An extended familiarity with electricity and its correlatives were brought to bear upon the question. It was not, however, until 1872 that the striking result was discovered by M. Gramme, that his electric generator was as equally efficient as an electric motor. This came from the fact that scientific men had educated themselves to reasoning backward. The magnetic and electrical conditions are convertible.

This singular coincidence attracted considerable attention, but its rapid development has been impeded and delayed by the counter attraction o electric lighting. Most of the dynamo machines now used may be employed as motors, and they occupy an important position as motive engines. A former paper treated upon the construction of the dynamo machine at considerable length; hence their construction need not enter into the scope of this paper. Examples might be enumerated, but, like other machinery, their construction should be as complete as possible in themselves. The earlier forms have been abandoned, and the present form of motor is designed closely upon the lines of successful dynamo electric machines.

With reference to their efficiency when employed as motors, we must first consider the mode of connection. In effecting the transmission of power by electricity, a dynamo machine is suitably connected by belt or gearing in any well-known form, and driven by a steam engine or other motive power. The dynamo generates a current of electricity, which passes through a leading wire to a second machine precisely similar, which can be placed almost any distance away.

The first generates the current, which, passing through the second machine, causes it to revolve and renders it capable of exerting mechanical energy. The amount of work done by the second machine, which in reality is the motor, is under favorable circumstances about 60 per cent. of that exerted by the first machine. The loss sustained is very small when compared with that involved in the transmission of energy by means of compressed air, water and other ponderable fluids. This had led naturally to the conception of electric railways, in which the cars should be propelled by an electric motor. It has been deemed feasible to transmit the electricity along the line through either rail, or by overhead wires, to supply current to the motor by frictional contact.

The actual energy is produced by a stationary machine situated any convenient place along the line, it only being necessary for a collector to continuously touch the current bearing conductor; this current passes through the motor and returns to the stationary machine through the other conductor which completes the circuit. A street railroad thus constructed would afford immunity from accidents, as the current could be immediately suspended in case of danger. It might also be instantly reversed. The car being entirely under the control of the driver, any desired velocity can be obtained. With electricity cars can be made to ascend a 5 per cent. grade with the same velocity as when running on a level.

The electric motor has been applied to a number of purposes of minor

description with marked success. There still exists a wide field for its development. Miniature apparatus of this kind may be made to yield surprising results within restricted limits, imposed by necessity for portability and lightness, notably for light pleasure boats. For lifts, hoists, elevators, sewing machines, millstone dressing, dentist's drills, actuating rock drills, stone engraving apparatus, wood engraving, etc.

This paper may, therefore, be considered as an attempt not only to elucidate the fundamental principles underlying these means of transmitting power, but also partially to explain the construction of the apparatus.

All the earlier forms of electric machines from the Pixi to the Saxton type produced alternating currents of electricity, that is, currents of a to-and-fro character, changing their direction as magnets of alternate polarity were rotated in front of the induction coils. At the same time all these machines were magneto machines. They were the forerunners of a type of dynamo, the most efficient and perfect and modernized representative of which is the present Brush machine, which uses a commutator to transform the to-and-fro currents into currents of continuous direction. All the older type of alternating machines were inefficient, beside being practically useless, as they were not suitable for lighting and electrolytical purposes, their only field of usefulness being restricted to electro-medical appliances. The tendency of electrical convention pointed to a continuous current mâchine, and for a time alternating current machines were forced into the background.

A new impetus was given to this type of machine by the invention of the Jablochkoff candle, which absolutely requires alternative current for its proper use. This took place during the years 1879 and 1881.

The most prominent electricians then bent their energies to the task of producing the desired machine, resulting in the Gramme alternator and the Lontine Siemens, which now serve as a basis of construction for modern machines, as the Westinghouse-Slattery, in this country. It is only very recently that dynamos have been thoroughly understood in all their more important details, and this understanding showed the faulty construction and wasteful energy of the old machines. In some, most of the energy was confined inside the dynamo, entailing a corresponding waste of coal and steam, and a destructive amount of heating in all parts of the dynamo.

The idea of magnetic friction was formerly unknown. A lump of iron is now considered as a large number of molecules forming such lump, and capable of rapid motion and also consumption of energy. Some of these dynamos actually required more driving power when not generating useful currents for lighting than when they were running with their full normal load on.

Going back a little, I will repeat that alternating currents are produced in coils of wire by being rapidly passed through magnetic fields of alternate polarity with such rapidity that the change takes place as often as 200 to 300 times per minute.

To increase the induction iron cores are placed into the rotating coils; it follows from the above facts that the wire core of these coils also pass 200 to 300 times per second through the magnetic fields of alternate

polarity, whereby the molecules of the iron core are rapidly vibrated an equal number of times. The inevitable result of such action and of such rapid and intense magnetic friction must be the development of heat, which accumulates in the mass of iron, lowering its magnetic conductivity, and finally burning out everything in contact with it. Hence we have some explanation of the rumors, and they are well founded on facts, of the many armatures of such alternating dynamos burning out.

Attention has therefore been directed to overcoming these defects by subdividing the iron in the armature cores by the use of thin hoop iron, or of thin sheets of the best soft wrought iron. The effect is at once apparent, and as an instance of it I mention the old 40-light Brush dynamo, which had its output raised from 40 to 65 lights by this subdivision. In alternating dynamos, however far the subdivision may be carried, the core is still liable to overheating, to burning out, and waste of energy. The question therefore presents itself as follows:

If iron cores get hot even when as minutely subdivided as is compatible with mechanical rigidity, such as is required for a rapidly revolving body, what else remains to be done? Simply to discard the iron cores entirely. Of course we thereby cut off the employment of all metals in the construction of the armature, wherever it is exposed to the action of the magnetic field.

We must now make the armature deprived of metal, which we have shown to be objectionable, of sufficient strength to stand say, 100 H. P., rotating at 1000 revolutions per minute.

So we propose a stationary armature instead of a rotating one, which entails, as a further consequence, the rotation of the formerly stationary field magnets. This armature contains no metal core; it will be very thin, say one-half inch thick, whereas formerly they were 2 to 3 feet long. This thinness will enable the field magnets to come close to each other and to the armature, providing an extremely intense magnetic field, so that a few turns of wire on the armature coils give a very high excitative and electromotive force. Such a dynamo would be practically indestructible, and of the highest attainable efficiency. Such a machine has been developed by Mr. Gustave Pfannkuche, marking out a new type of alternating current machines.

Naturally the question will be asked, Why do you employ alternating currents instead of continuous? We use both for their respective purposes: the continuous for direct lighting; as, for instance, a low tension for incandescence lamps and a high tension for arc lamps. Of late the demand has been for incandescence lamps a long distance from the generating station; this demand has become so great that it could no longer be ignored. Incandescence lamps in private houses require low tension currents, but these currents cannot be sent over long distances without very great loss. Therefore high tension currents are sent over long distance lines, and these high tension currents are converted to low tension currents at the point of consumption. This is accomplished by means of alternating current and converters, both well understood, though, perhaps, under other names.

All are familiar with the old Ruhmkorf coil, with its attendant battery and interrupter. This coil converts low tension currents into high ten-

sion, whilst our more modern constructed coil converts high tension into low tension, and instead of alternating a continuous battery current by mechanical device, we directly produce currents of alternating or pulsatory type from our dynamo, a difference in degree and in construction only, but not in theory and effect. This is why we use alternating dynamos for long distances, converting at the point of distribution. There are systems which seek to reduce high tension currents into low tension ones by means of continuous current apparatus, but such schemes apparently will fail of commercial success on account of the great expense, and the necessity of moving the machinery to points of conversion and consumption.

While the alternate converter is apparently an inert mass of iron wire and copper wire, with no movement to it that can ever be apparent to our eyes, yet our mental eyes see it, a mass of rapidly vibrating molecules always in a seeming hurry to get there, and yet never doing so, whereby they greatly distinguish themselves from the enterprising members of the Civil Engineers' Club, of Cleveland.

DISCUSSION.

After reading his paper, Mr. Possons made a blackboard diagram to exhibit the method of burning incandescent lamps on the same circuit from the arc machine by means of multiple series cut out.

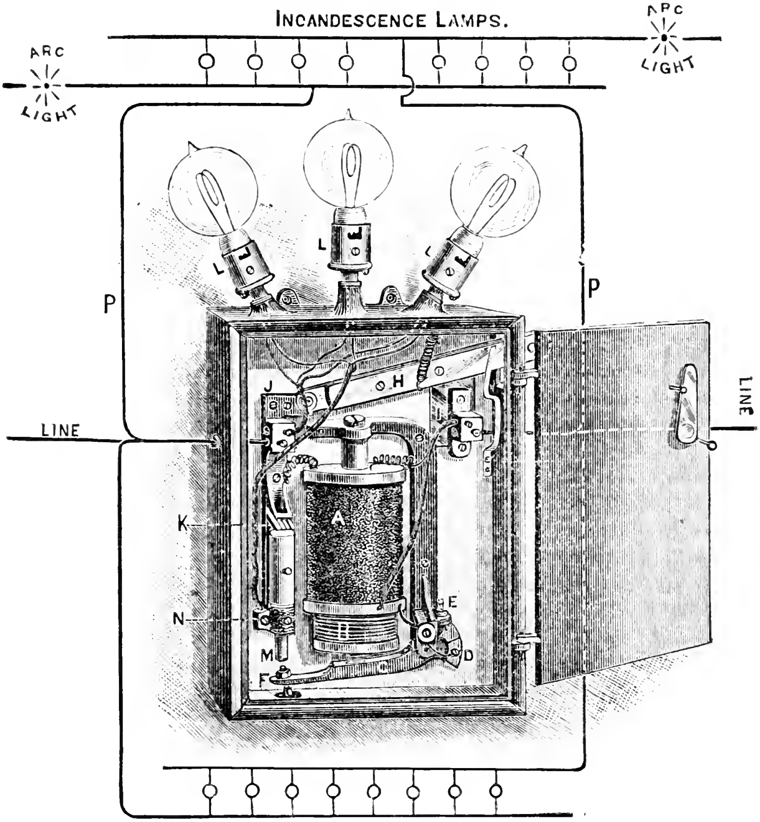
Mr. Warner : In what does the difference between the high and low tension consist ?

Mr. Possons : The difference between a high and low tension machine may be arranged entirely by the copper wire which we put upon this machine. High tension machines are usually wound for a constant current with a variable E. M. F. (electromotive force), due to the load put upon the machine. As for instance, in the arc machine, each additional lamp in the circuit requires 45 volt E. M. F. These high tension machines are usually wound with a fine wire, while the low tension machines are wound with a very much heavier wire, the internal resistance of the incandescence machine, or low tension machine, being very small.

(In compliance with the request of a member, Mr. Possons drew another diagram.) Mr. Possons (pointing to diagram): Suppose we imagine this to represent an arc machine; these will represent the arc lights. You notice that the current is continuous. It extends from one binding post, which is the positive of the machine around the circuit, to the other. Now, to burn incandescence lamps upon an arc circuit, we loop in, as shown on the diagram, and run the incandescence lamps in a loop, termed parallel circuit. With an ordinary 16 candle-power lamp of 50 volts E. M. F. we can burn eight lamps in the loop. This loop takes the place of one arc lamp. The resistance of these lamps is about 50 ohms each. Now, by burning in parallel, the resistance of these eight lamps is about $6\frac{1}{4}$ ohms.

You will also note from the diagram that the main spool is wound with two thicknesses of wire ; the large wire, to carry the current, and the fine wire coupled in parallel. All are familiar with the fact that a certain portion of the current will go through the fine wire, due to the

resistance of that fine wire. Now, we will suppose that one lamp breaks, either through carelessness, or from natural causes. The resistance of this loop is thereby increased, so that instead of measuring $6\frac{1}{4}$ ohms it now measures $7\frac{1}{7}$ ohms, so that in ordinary cases more current would pass through this loop, thereby breaking, perhaps, the lamps contained therein. To avoid this we have placed three lamps on the top of the M. S. (Multiple Series) cut-out box. These are termed pilot lamps, and are known as safety lamps. Now should more lamps break in this loop



until the whole number (including the pilot lamps) should number seven, the whole M. S. would be cut out of the circuit as will be shown by a study of the diagram.

Mr. Walker : How is it that three pilot lamps will burn at once?

Mr. Possons answered this question by a black-board illustration, showing that three pilot lamps are placed in parallel so that all must burn.

Mr. Walker: Your company puts on a little attachment for incandescence lamps in our office.

Mr. Possons: An automatic cut-out. This is constructed in the form of a horseshoe magnet, so arranged that the armature is placed on the

open end of the horseshoe. When the current from the machine runs through the lamp the armature closes the circuit in one direction, while, when the lamp breaks from any cause the armature shifts, closing another connection, which forces the current through a fine german silver wire, this german silver wire absorbing the same current which the incandescence lamp does when burning. It is assumed that a 50-volt lamp absorbs about 1.2 ampères.

Mr. Walker: We had an attachment that would act when it should not.

Mr. Possons: This was due to the want of proper adjustment on the part of the attendant, and due to the fact that the lamps were high potential lamps, and burning, of course, with a small amount of current, the current being so small and the variation of the arc circuit being so great that it was not regarded as automatic. We therefore recommend 50-volt lamps for M. S. cut-out work, and not 92-volt, as were formerly put in your works.

Mr. Walker: They are working satisfactorily now.

Mr. Possons: That is due to the fact that your 92-volt lamps have been exchanged for 50-volt lamps.

Mr. W. R. Warner: With regard to lighting houses, I noticed in Chicago that several large houses have gas engines.

Mr. Possons: As gas engines have recently been made, I think it is practicable to run with them. Water power is considered superior to anything else on account of its steadiness. There is nothing that appears to answer the purpose as well. I have great hopes of the alternating system for lighting houses.

Mr. Warner: How much light can be gained over enough gas to give 1,000 candle-power 100 hours? How economical is it?

Mr. Possons: I should estimate that the loss would be about 40 per cent. from the engine to the light.

Mr. Warner: I have seen it stated that you can get as much light from an incandescent as the gas would give.

Mr. Possons : The incandescence machines give from 83 to 85 per cent. efficiency.

Mr. L. Herman : Might not the gas have considerably more heat energy than light-giving energy?

Mr. Possons : I should assume that there must be some loss in the light.

Mr. Herman : Gas produces a certain amount of heat as well as of light. If we use gas in a gas engine we get the benefit of the heat energy and waste the light energy. Some gases give a great deal of heat and no light at all. The gas generally manufactured in our cities contains a great amount of heat ; it is better adapted for heating than for lighting.

Prof. Morley: I have seen a gas engine driving a dynamo and supplying incandescent lights. The gas consumed in the engine gave more light in the incandescent lamps than if it had been burned in ordinary burners. By burning gas in the cylinder of the engine, you can utilize not only that portion of its energy that appears as light in the ordinary gas flame, but also that portion that does not appear as light. If gas en-

gines are improved, and if gas companies furnish us a cheaper gas to be used as fuel in gas engines driving dynamo-electric machines, we may well hope that in time the increase in the quantity of light thus produced will pay for the interest, depreciation and care of the machinery.

Mr. Walker: Can Mr. Possons explain to us the arrangement of the wire for running the electric railways?

Mr. Possons: I have not made any particular examination of the methods. The Sprague Company use one overhead wire returning by the track. They are also running a separate wire attached to the rails. To insure good connection I should prefer two wires overhead. In the Sprague system the positive current will go overhead. This is what is called the parallel system, and is explained by this diagram. The wires running overhead and suspended are held in place by wires running across the street, the return circuit being through the rail and back to the machine. With the parallel circuit the current goes from the machine through the motor and back to the machine. For the second car, the current goes also from the machine through the second motor back to the machine and so on. It, therefore, has a resistance of that part of the circuit intervening between the machine and each motor. The series system runs through the entire line and back to the machine, so that the power absorbed is the resistance of the entire line, plus the power requisite for the propulsion of the car by the motor. It is conceded that with the many motors run by the parallel system over one circuit the loss is very great, while in the series system, the entire loss is as great in one motor as in the whole series of motors. By this I mean that the resistance in the line is the same in the series system, no matter how many are running.

Mr. Herman: The side connections made about every 500 feet in the Sprague electric railway are a safety device. They carry the current from the feeder to the central wire every 500 feet, so that if break should occur it would only affect 500 feet of the line. The rest of the system could be kept running even if there should be a break in any of the sections.

Mr. Warner: I wish Mr. Possons would make a sketch on the board of the Jablochkoff candle.

Mr. Possons: We regard it as very much out of date now. This is according to my recollection of it. (Makes diagram.)

It was two sticks of carbon placed side by side, and the space was filled with plaster of Paris. A connection was made that enabled it to start, the plaster of Paris was heated, and finally it recalcined of itself and fell away. It did not come into general use. It was mainly used in Paris; it was also used in New York in the earlier days of electric lighting.

Mr. Whitelaw: Two or three years ago there was a project for utilizing the power of Niagara Falls for electric lighting at Buffalo.

Mr. Possons: The principal difficulty is the vast amount of capital it would require to run a sufficiently large wire without too much loss from the power; perhaps with a $\frac{3}{4}$ inch conductor the loss would not be so great. We figure generally that about two miles of number 8 wire is equivalent to about $4\frac{1}{2}$ ohms, or one arc lamp. I think it would require about an inch wire and the loss then would be wonderful. If

parties are willing to spend the money for the plant, they would, no doubt, get a great deal of power, and very steady power, but it would be cheaper to build the manufactory somewhere else.

We know nothing that is a perfect insulator nor a perfect conductor; we get the best we can. We have recently completed for the Hayward & Hobart Co., Virginia City, Nevada, a motor plant, probably the largest in the world. They have a mine 1,500 feet under ground—1,500 feet water pressure. There is little wood and less coal in the neighborhood. We made a special generator and attached to this a Pelton water wheel. This wheel had a capacity of about 125 horse-power, and from the depth of this mine, 1,500 feet under ground, they ran wires and transmitted the energy through these wires to an 80 horse-power motor placed at the outside of the mine. The efficiency of this motor was fully 90 per cent., and the variation in speed from no load to full load was about 3 per cent. I understand these motors are now working very satisfactorily.

Mr. Whitelaw: I have understood that the electric spark will not ignite natural gas.

Mr. Possons: That is the case, but it will ignite illuminating gas.

Mr. Whitelaw: Some of the workmen in the tunnel said that it was the electric spark that caused the explosion. I made inquiries and found that the current had ignited the insulator, and from that the gas was ignited.

Prof. Morley: I have ignited natural gas from the electric spark many times. Coal gas contains a large quantity of hydrogen, which ignites at a low temperature, and so even a feeble electric spark is sufficient. Natural gas contains but little hydrogen and you have to get a degree of heat sufficient to ignite marsh gas before you can light natural gas; still it can be done.

Mr. Whitelaw: Electricity is now used in fusing and welding metals.

Mr. Possons: That is done very successfully. It is hardly possible to refer to all the uses of electricity in one paper.

Prof. Morley: I understand that they propose to produce currents of 20,000 ampères.

Mr. Possons: I believe that is proposed.

Mr. Force: I saw in Brooklyn, lately, seamless steam boilers welded with gas; the boilers were complete without a rivet.

Mr. Possons: Is not that done without destroying the fibre of the iron

Mr. Herman: Yes, sir.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

FEBRUARY 20, 1889:—A regular meeting was held at the Society's room, Boston & Albany Railroad Station, Boston, at 19:30 o'clock, President FitzGerald in the chair. Sixty-four Members and fourteen visitors present.

The record of last meeting was read and approved.

Mr. William O. Webber was elected a Member of the Society.

The following were proposed for membership:

T. T. Hunter Harwood, Rockport, Mass., recommended by Sophus Haagensen and E. P. Adams: Charles W. Howland, Rockland, Mass., recommended by E. L. Brown and C. W. S. Seymour, and George A. Wetherbee, Malden, Mass., recommended by N. H. Crafts and S. E. Tinkham.

On motion of Mr. Manley, it was voted that a committee of three be chosen by nomination at large to present a list of candidates for officers of the Society for the ensuing year, three names to be presented for each office, and that the Committee be requested to report its nominations with the notices of the annual meeting. The following were chosen as that Committee: H. Bissell, H. L. Eaton and F. L. Fuller.

The President, for the Government of the Society, reported its recommendation that the letter from the Engineers' Club of Kansas City, in relation to the transfer of Members, be referred to the Committee on the Revision of the Constitution. On motion of Mr. Brooks the recommendation was adopted.

On motion of Mr. Howe, the Secretary was requested to convey to the American Watch Company the thanks of the Society for the courtesies shown the Members of the Society on the occasion of the visit to Waltham.

The President announced the death of Samuel M. Felton, an honorary member of the Society, which occurred on January 24, 1889; also that of Edward S. Philbrick, a past vice-president, which occurred on February 13, 1889, and spoke briefly of the life of each.

On motion of Mr. Manley, the President was requested to appoint a committee to prepare a memoir of Mr. Felton. The President named as the committee Charles Harris and Thomas Doane.

On motion of Mr. McClintock it was voted that the President and two other Members, to be selected by him, be a committee to prepare a memoir of Mr. Philbrick. The Committee as selected consists of Desmond FitzGerald, Albert H. Howland and Walter Shepard.

The Secretary presented on behalf of the several donors portraits of the first three presidents of the Society. The portrait of the first president of the Society, James F. Baldwin, is a photographic reproduction of an oil painting in the possession of the Massachusetts Historical Society, and is the gift of a number of the members of the Society, who have in addition given the frames for all three of the portraits. The portrait of the second president, George M. Dexter, is the gift of his daughter, Mrs. James J. Storrow, of Boston, and is the copy of a beautiful crayon drawing by Rowse. The portrait of the third president, Simeon Borden, is the individual gift of our present president, and what adds greatly to its value for the Society is the fact that it is the work of his own hand.

Mr. Thomas Doane gave a short account of the life of Mr. Baldwin, and the Secretary read the following short sketch of the life of Mr. Dexter, prepared by Mr. George L. Vose.

George Minot Dexter was born in Boston, November 15, 1802, and died in Brookline, November 26, 1872. His father was Dr. Aaron Dexter, who graduated from Harvard College in the class of 1776, and was a physician in Boston and Professor of Materia Medica in Harvard University. His mother was Rebecca Amory, daughter of Thomas Amory, a prominent merchant in Boston. Mr. Dexter entered Harvard College with the class of 1821, but did not graduate. He married a daughter of Thomas C. Amory, of Boston, and lived in this city until 1855, when he removed to Longwood, in Brookline.

Mr. Chas. S. Storrow, who had a long and close acquaintance with Mr. Dexter, sends me the following in regard to him: "My first intimacy with Mr. Dexter, although I had very slightly known him before, was in Paris, in the year 1830, where I was studying engineering and he was residing for the benefit of his health, which was very delicate. He was at that time interested in engineering matters, which we often discussed, but much more in architecture, for which he had an especial liking. He was not connected, however, as far as I remember, with any institution giving instruction in that branch. He returned to Boston, I think, in the year 1831, and entered as a pupil the office of Col. Loammi Baldwin, the eminent engineer, then engaged in the construction of the dry docks at the Charlestown and Norfolk navy yards. In that connection he had the use of Col. Baldwin's magnificent library of engineering works, together with familiar intercourse with him, the most genial of men, and an opportunity to copy or draw plans, and watch the various operations connected with the construction of those great works. About the year 1834 he came, as one of the assistant engineers, into the service of the Boston & Lowell Railroad, which was then being constructed by Col. James F. Baldwin as chief engineer, in which service I had myself been engaged as an assistant for some years previous. Upon the completion of the work in the summer of 1835 he was appointed superintendent and general manager of the business of the road, which office he retained until the spring of 1836, when he relinquished it at the suggestion of Mr. Patrick T. Jackson to engage in the planning and building of houses and stores upon the Gardner Green estate, then graded and laid out as Pemberton Square. From this time forward I think he devoted himself almost entirely to architectural pursuits, planning and erecting houses, stores and public buildings, being, however, at the same time connected with the construction of some other New England railroads and superintending various improvements in the Jamaica Pond water-works, the infant predecessor of the Cochituate."

Mr. Dexter was for many years closely connected with the affairs of Trinity Church, being at the time of his death the Senior Warden. After the burning of the church in Summer street he worked very hard superintending the removal of the bodies from the vaults beneath that building to Mt. Auburn: and, having been much exposed, caught a bad cold, which resulted in a few days in congestion of the lungs, which caused his death.

Mr. Dexter's private character was one of great purity, unselfishness and attractiveness. No one ever came in contact with him without feeling the better for it. His religion was not confined to one day in the week, but was of the practical kind that made itself constantly felt in all of his intercourse with others through a long and useful life.

The Secretary also read the following account of Mr. Borden's life:

Simeon Borden, the third President of the Boston Society of Civil Engineers, was the oldest son of Simeon and Amy Briggs Borden, having been born at Fall River, June 29, 1798. His early life was spent in attendance upon the district school, which at that time could do but little toward furnishing the elements of a

good education. He soon evinced a strong desire to engage in a more agreeable employment than the ordinary routine of a farmer's life, and, accordingly, sought to enlarge the circle of his ideas by reading and the study of geometry and mathematics. A library was established in the neighborhood, in which he was deeply interested.

New views, new thoughts and new feelings sprang up together, urging him to press further and further on in the pursuit of knowledge, until he had attained by his own industry a high position among the scientific men of his day.

His first practical attempts were in land surveying. Finding the compass then in use so imperfect that nothing like an accurate survey could be made, he devised one for himself which gave much better results. In 1828, he took charge of the Pocasset Machine Shop in Fall River, and there in 1830 constructed a measuring rod for the State of Massachusetts with which to lay off the base line of the State survey, then just begun. The apparatus was 50 feet long, inclosed in a tube, and so constructed as to remain of an invariable length in all temperatures. It was the most accurate and convenient instrument of the kind extant, and has since been surpassed only by that of the United States Coast Survey. It was a most difficult piece of work, as nothing of the kind had ever been made before. Forced therefore to rely wholly upon his own resources, by repeated experiments and many computations he at last found his work crowned with success.

Mr. Borden was appointed one of the engineers to carry on the triangulation of the State, and in 1834 was made chief of the corps. With limited means and imperfect instruments Mr. Borden's genius, resources and patience were taxed to the utmost, but the correctness of his work has been satisfactorily tested again and again since the completion and publication of the results of the work.

Mr. Borden was subsequently employed to run the boundary line between Massachusetts and Rhode Island, as settled by the Supreme Court of the United States in 1844; in the survey for the Cape Cod Railroad, and others in Maine and New Hampshire, and in 1851 accomplished a difficult feat by suspending a telegraph wire across the Hudson River, a distance of more than a mile, upon masts 220 feet high. In 1851 he published a volume entitled, "A System of Useful Formulæ adapted to the Practical Operations of Locating and Constructing Railroads." He was also called upon as an expert witness in the trial of cases relating to mechanical inventions. For this work he was eminently qualified.

At the time of his death, October 28, 1856, he was President of this Society and a member of the American Philosophical Society, American Academy of Arts and Sciences, and other societies of a similar nature. In his private life he was a model of integrity and honor.

On motion of Mr. Herschel, the Secretary was requested to express to Mrs. James J. Storrow the thanks of the Society for her gift.

On motion of Mr. Doane, the Secretary was also instructed to convey to President FitzGerald the thanks of the Society for his generous gift.

Mr. Henry Manley opened the discussion of the evening with a paper on "Rapid Transit in Boston." Mr. Albert H. Howland followed with a paper on the same subject. In the general discussion the following Members took part: C. F. Allen, F. Brooks, Clarke, Doane, Herschel, E. W. Howe, Oliver, C. H. Parker, Plimpton, L. F. Rice and others.

[*Adjourned.*] S. E. Tinkham, Secretary.

ANNUAL DINNER.

March 6, 1889:—The seventh annual dinner of the Boston Society of Civil Engineers took place at Young's Hotel, Boston, Wednesday, March 6. An informal reception was held at five o'clock, and at six o'clock Members and their guests to the number of 99 sat down to dinner.

The cover of the menu was designed by one of the Members, Professor Burton, and represented the target of a Boston leveling-rod, with sketches of local public works in its four sections.

President Desmond FitzGerald sat at the head of the table, having on either hand as the guests of the Society, President Charles W. Eliot, of Harvard University; Mr. William P. Shinn, representing the American Society of Civil Engineers; Prof. Thomas M. Drown, representing the American Institute of Mining Engineers; Col. Samuel M. Mansfield, Corps of Engineers, U. S. A.; Lieutenant-Commander Joseph G. Eaton, U. S. N., and Mr. Hiram Nevons, President New England Water-Works Association.

President FitzGerald in calling the Members to order, after ample justice had been done to the excellent bill of fare, spoke briefly of the history of the Society, and congratulated the members upon its growth during the past year. He extended a cordial greeting to the larger, though younger, sister engineering societies of the country, and introduced Mr. Shinn, of the American Society of Civil Engineers. Mr. Shinn expressed the cordial feelings entertained by the American Society toward the local societies, and spoke of the large and extended membership of that Society and of its efforts to improve the standing of the profession.

Professor Drown responded for the mining engineers. He showed how largely the civil was indebted to the mining engineer for the materials for his structures, and hoped, in order that harmony might prevail between the two professions, that the civils would be content with such physical tests as they might make on the materials furnished by the metallurgists, and not embarrass the latter by specifying too minutely the chemical proportions that shall enter into the compositions.

President Eliot spoke of the antiquity of the engineer's profession, and closed with an earnest appeal for permanency and beauty in the structures erected.

Colonel Mansfield gave an account of the organization of the United States Engineers Corps and of the work it was called upon to perform.

Lieut. Commander Eaton spoke of the ordnance work of the Government and of the improved methods and quality of materials now used.

Past President Rice alluded to the difficulties encountered by the engineer in making his structures as beautiful and as permanent as he desired, and to the fact that too often it was the simple question of doing the work in a rude and temporary way or of not doing it at all.

Mr. Leavitt spoke for the mechanical engineer, and gave a very interesting account of some of the large iron and steel manufactories abroad, and Mr. Eliot Holbrook responded for the railroad engineer. The other speakers upon whom the President called were: Messrs. Billings, Brooks, Cheney, Ellis, E. W. Howe, H. M. Howe, Manley, McClintock, Swain, Tidd and Tilden.

S. E. TINKHAM, Secretary.

ANNUAL MEETING.

MARCH 20, 1889 :—The annual meeting of the Boston Society of Civil Engineers was held at its room, Boston & Albany Railroad Station, Boston, at 19 o'clock. President FitzGerald in the chair. Seventy-four Members and twelve visitors present.

The record of the last meeting was read and approved.

Messrs. T. T. Hunter Harwood, Charles W. Howland and George A. Wetherbee were elected Members of the Society.

The following were proposed for membership: William C. Boyce, Worcester, Mass., recommended by L. A. Taylor and Richard Forbes; Edmund Grover, East Walpole, Mass., recommended by F. P. Spalding and G. A. Nelson; Francis E. Hosmer, Boston, recommended by Henry Manley and E. W. Howe, and Frank B Rowell, Lynn, Mass., recommended by H. Bissell and J. P. Snow.

The President announced the death of William S. Barbour, a Member of the Society, which occurred February 24, 1889, and on motion of Mr. Stearns, the President was requested to appoint a committee to prepare a memoir. The President named as that committee Messrs. George A. Kimball, Albert F. Noyes and George E. Evans.

The Secretary presented and read the report of the Committee on Weights and Measures. The report was accepted and ordered to be printed.

Mr. McClintock, for the Committee on National Public Works, submitted a verbal report, and asked for further time in which to present the written report. On motion of Mr. Manley it was voted to continue the Committee for another year as now constituted.

Mr. Howe presented and read the report of the Committee on Excursions. The report was accepted and ordered to be printed.

Mr. Woods presented and read the report of the Committee on Library. The report was accepted and ordered to be printed.

Mr. Stearns presented and read the report of the Committee on Revision of the Constitution. On motion of Mr. Rice, the report was accepted, and the Committee continued as now constituted.

Mr. Cheney, for the Committee on Highway Bridges, and Mr. Doane, for the Committee on Common Headquarters, submitted verbal reports asking for further time. It was voted to continue both Committees as now constituted.

The Secretary read the annual report of the Government of the Society. The report was accepted and ordered to be printed.

The Treasurer submitted his annual report, approved by the Auditor. The report was accepted, and an abstract ordered to be printed.

On motion of Mr. Brooks it was voted that the special committees on Weights and Measures, on Excursions, and on the Library, be continued, and that the membership of the same be left with the Government with full power.

On motion of Mr. Manley an assessment of $6 was levied on all Members of the Society.

On motion of Mr. Howe, the Secretary was requested to convey the thanks of the Society to the Thomson-Houston Electric Company and the Thomson Electric Welding Company, for courtesies shown the Members on the occasion of the visit to Lynn.

On motion of Mr. Rice, it was voted that the thanks of the Society be expressed to Mrs. Edward S. Philbrick for her generous gift to the library.

The Society then proceeded to the election of officers for the ensuing year, with the following result:

President, Desmond FitzGerald.

Vice-President, John R. Freeman (third ballot).

Secretary, S. Everett Tinkham.

Treasurer, Henry Manley.

Librarian, Frank W. Hodgdon (fourth ballot).

Member Board of Managers, Winfield S. Chaplin.

President Desmond FitzGerald then delivered the annual address, which was very fully illustrated by lantern views.

(*Adjourned.*) S. E. TINKHAM, Secretary.

ANNUAL REPORT OF THE GOVERNMENT OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

In accordance with the requirements of the constitution the Government submits the following report on the affairs of the Society :

The past year has been one of marked prosperity. A larger number of names has been added to our list of Members than in any former year, the attendance at

the meetings has been greater and the social gatherings have been made a more prominent feature than ever before. Your Treasurer's report shows a net gain of $411.99 to the funds of the Society. The report of the Librarian shows an addition to the list of books in the library of 425 numbers.

At our last annual meeting the total membership was 193, 5 honorary and 188 active Members. During the year now ended there have been 4 deaths, 2 resignations and 5 names dropped from the list, making a total loss of 11. There have been added 37 new Members, making a net gain of 26. Our present list comprises 4 honorary and 215 active Members, a total of 219.

During the year ten regular meetings have been held, and the annual dinner this year was made a separate gathering. At the ten regular meetings, the attendance has aggregated 700, of whom 556 were Members and 144 were visitors. The smallest attendance at any meeting was 48, and the largest 114, the average being 70, an increase of 43¾ per cent. over last year. The attendance at the annual dinner was 99.

Papers have been presented at all of the regular meetings, as shown on the following list:

April Meeting:—Method and Apparatus Used in the Test of Water Meters in Boston, by L. F. Rice; Notes on the Water Meter System of Providence, by E. B. Weston.

May Meeting:—Construction and Ventilation of Small Pipe Sewers, by W. E. McClintock. Written discussions on the same subject by members and others.

June Meeting:—Description of the Quincy Dam, by L. A. Taylor; Description of the Lawrence Dam, by R. A. Hale: Description of the Stony Brook Dam, by W. S. Barbour, which was illustrated by lantern views; An Account of the Wooden Dams Built by the Schuylkill & Susquehanna Navigation Company, by Edwin F. Smith; Percolation Through Embankments, by John R. Freeman; Descriptions of the Embankments Constructed at Chestnut Hill and Parker Hill Reservoirs, by W. F. Learned.

September Meeting:—Removal of Roof Water, by Dwight Porter; House Drainage, by J. Pickering Putnam.

October Meeting:—Construction of Farm Pond Conduit, by H. H. Carter; Testing a Barrenburg Rotary Pump, by R. A. Hale; A Paper on Time Reform, by Fred. Brooks.

November Meeting:—Memoir of Henry F. Walling, by a Committee of the Society: Flushing Tunnel at Milwaukee, Wis., by J. D. Mason; Description of the New Croton Aqueduct, by Alphonse Fteley, which was illustrated by lantern views.

December Meeting:—Stadia Work, by J. R. Freeman, and discussion on methods for topographical work.

January Meeting:—Duty Trials for Pumping Engines, by G. H. Barrus.

February Meeting:—Rapid Transit in Boston, two papers, by Henry Manley and Albert H. Howland.

In furtherance of the second object of our organization, the encouragement of the social intercourse among the Members the year just past has been unquestionably most successful.

Through the diligence and skill of the Excursion Committee, nine excursions have been made during the year to works of professional interest, and the large number of Members who have attended shows conclusively how pleasant and profitable has been this part of our year's work.

During the year, through the liberality of a number of the Members and friends of the Society, there have been hung upon the walls of our room excellent portraits of the first three presidents of the Society, James F. Baldwin, George M. Dexter and Simeon Borden.

It is our sad duty to record the deaths of four of our Members since the last

annual meeting: Samuel M. Felton, an Honorary Member, died January 24, 1889. Edward S. Philbrick, a Past Vice-President, died February 13, 1889. Henry F. Walling died April 8, 1888, and William S. Barbour died February 24, 1889.

Three new special committees have been appointed during the year, one to consider if any changes are advisable in our Constitution and By-Laws, another to confer with other scientific societies in Boston on the practicability of occupying common headquarters, and a third to consider what steps can be taken to improve the condition of our highway bridges.

As the Government has submitted from time to time such recommendations as it had deemed advisable, at this time it has but the single recommendation to make, that the usual annual assessment of $6 be levied upon all Members not exempted therefrom by the Constitution.

Respectfully submitted,

DESMOND FITZGERALD, President.
F. P. STEARNS, Vice-President.
S. E. TINKHAM, Secretary.
HENRY MANLEY, Treasurer.
H. D. WOODS, Librarian.

BOSTON, March 20, 1889.

ABSTRACT OF TREASURER'S REPORT FOR THE FINANCIAL YEAR, 1888–89.

Receipts.

Cash at beginning of year	$111.31
Non-resident dues, current year	64.00
Non-resident dues, coming year	140.00
Assessment levied March 21, 1888	882.00
JOURNAL for new Members	73.75
From a Member	4.00
Interest on deposits	12.78
Sales of JOURNAL	3.25
	$1,291.09

Expenditures.

For JOURNAL	$648.50
Binding	19.35
Periodicals	41.39
Printing	151.25
Postage and stationery	67.55
Annual dinner	44.50
Secretary's salary	100.00
Expense of meetings, repairs, etc	43.75
Cash on deposit	174.80
	$1,291.09

PERMANENT FUND.

Receipts.

On hand at beginning of year	972.56
Admission fees	366.00
Interest and dividends	122.00
	$1,460.56

Expenditures.

Nine shares C., B. & Q. R.R. stock	$1,039.50
Cash on deposit	421.06
	$1,460.56

Schedule of the Property of the Society in the Hands of the Treasurer, March 20, 1889.

One Republican Valley Railroad bond, par	$600.00
One A., T. & S. Fe Railroad "plain 5" bond, par	1,000.00
Nine shares C., B. & Q. stock	900.00
Cash on deposit	595.86
	$3,095.86
Schedule last year	2,683.87
Net gain	$411.99

HENRY MANLEY, Treasurer.

REPORT OF THE COMMITTEE ON WEIGHTS AND MEASURES.

To the Boston Society of Civil Engineers :

In accordance with custom, your Committee on Weights and Measures respectfully presents its annual report, as follows:

Your Committee is not informed that any radical change in the use of weights and measures has occurred during the past year.

The International Congress.

President Harrison will probably soon appoint ten delegates to the Commercial Congress, to convene in Washington on October 2, of this year, at which representatives from the Republics of Mexico, Central America, South America, Hayti, San Domingo and the Empire of Brazil have been invited to be present. This Congress was provided for by the Act of Congress of May 24, 1888, but the Commissioners were not appointed by President Cleveland.

The conference is to consider measures to preserve the peace and promote the prosperity of the several American States; the formation of an American customs union; the establishment of regular and frequent communication between the ports of the several States; the adoption of a uniform system of weights and measures, and international patent and copyright laws; the adoption of a common silver coin, and an agreement upon and recommendation for adoption to their respective goverments of a definite plan of arbitration of all questions, disputes, or differences, to the end that they may be peaceably settled and wars prevented.

The deliberations of the Congress regarding the adoption of a uniform system of weights and measures will tend strongly towards the adoption of the metric system, since each government is to have a single vote, and nearly if not quite all the nations south of the United States already use the metric system for customs and other official business, and the use of this system is already legal in the United States.

The New England Railroad Club.

At the January meeting of the New England Railroad Club the subject of the metric system was discussed and the following resolution was adopted, viz.: "That the New England Railroad Club recommend that the Executive Committee of the Master Car-Builders' Association appoint a committee on the metric system of weights and measures, to report at the next annual meeting of the Association."

The passage of this resolution has occasioned much discussion in technical journals.

The National Association of Builders.

At the third annual convention of the National Association of Builders of the United States, held at Philadelphia, in February, Prof. George Eastburn read a paper entitled "The Metric System," and a committee was appointed to take into consideration the absurdities of the present system of weights and measures.

The Metric System in Germany.

The report of the Committee on the Metric System, of the Western Association of Architects, contains the following letter from Mr. D. Adler, of that Association, regarding the introduction of the metric system in Germany:

"CHICAGO, November 15, 1888.

"*N. S. Patton, Esq., Chairman, etc.:*

"MY DEAR SIR: In obedience to the promise made you, I made inquiries during my stay in Germany last summer as to the difficulties encountered in the intro duction of the metric system in that country. These inquiries were directed particularly to two points: First, whether there were any serious inconveniences and

disturbances incidental to its first introduction; *i. e.*, whether at first it had been found difficult, to those accustomed to the use of the old system, to think and express their thoughts and knowledge under the new system. The other point was whether any inconveniences resulted from the decimal division and its failure to lend itself readily to a division into halves, quarters, etc. Upon both of these points the answers received from architects, manufacturers, engineers, and merchants whom I consulted, were favorable to the metric system. I was told that comparatively few errors were made in the earlier days of its use; that even the older people, who had grown gray in the use of the old system, had found no serious difficulty in adapting themselves to the new weights and measures, and that these older persons appeared to prize the new system more highly than the younger people who had never known the intricacies and difficulties of the old systems of weights and measures.

"As to the second point, I found some difference of opinion, but there was a great preponderance of evidence to the effect that no inconveniences had resulted from the necessity for calling a half five-tenths, or a quarter twenty-five hundreths, etc.

"On the whole, all united in the statement that had the difficulties incidental to the introduction of the metric system been ten times as great as they were really found to be, the resultant advantages would have much more than outweighed them, and that for no consideration would they wish to return to the old system. (Signed) D. ADLER."

The International Bureau.

Your Committee regrets to report the recent death of Dr. O. J. Broch at Paris, February 5, 1889, at the age of 71 years. Dr. Broch has been identified for many years with the higher branches of physics and metrology, and has been for several years Director of the International Bureau of Weights and Measures at Paris. This Bureau was established in 1875 by a convention entered into by sixteen States of the old and new worlds, of which this country was one. The principal aim of this institution is to preserve and perpetuate for all these States true units of metric weight and measure, by furnishing them standards of weight and of length which shall be as nearly as possible identical in material and construction, and whose weight or length shall have been rigorously established with reference to international prototypes of the meter and kilogram, of which the Bureau has exclusive charge. Respectfully submitted,

CHARLES H. SWAN, Chairman,
for the Committee.

BOSTON, March 20, 1889.

REPORT OF COMMITTEE ON EXCURSIONS.

BOSTON, March 20, 1889.

To the Boston Society of Civil Engineers:

The Committee on Excursions submit the following report on the matter placed under their direction during the past year.

The Committee have endeavored to arrange for an excursion to some place of engineering interest upon the afternoon of the day of each regular meeting of the Society. This plan has been carried out except upon two occasions. The Committee, consisting entirely of new members, was unable to meet together for organization in season to arrange for an excursion upon the day of the April meeting, and upon the day of the January meeting the annual meeting of the American Society of Civil Engineers was held in New York, and there was also a meeting of the New England Water-Works Association in Boston; so many Members being in attendance upon these meetings it was thought best to omit the usual visit. There have

been eight of these monthly excursions, of which the following is a statement of the dates, the places visited and the number present :

DATE.	PLACE VISITED.	Number present.
May 16, 1888	The Chadwick Lead Works and Boston Heating Co.'s Works.	40
June 20, 1888	The Boston Marine Park Pier	20
	(It was rainy in the early part of the afternoon, which was probably the reason of the small number present.)	
Sept. 19, 1888	The Boston Stony Brook Improvement	29
	(Another rainy afternoon.)	
Oct. 17, 1888	Harvard Bridge	32
Nov. 21, 1888	Boston & Maine R. R. bridge across the Merrimack River at Newburyport	48
Dec. 19, 1888	Electric R. R. of the West End Street R. R. Co	70
Feb. 20, 1889	American Watch Co.'s factory at Waltham	55
Mar. 20, 1889	Thomson-Houston Electric Co.'s factory at Lynn	42
	Average attendance	42

In addition to the above, which may be called the regular monthly excursions, there took place on August 25, 26 and 27 what has come to be named "the annual excursion" of the Society.

The Members with their ladies, the whole party numbering 52, left Boston via the Providence Division of the Old Colony R. R., at 8 o'clock, August 25, and arrived at Providence at 9:35, where a part of the day was spent in visiting various public works; at 15 o'clock the party left Providence for Rocky Point by steamer. After enjoying a Rhode Island Clam-Bake, the sail down the bay was continued, and at 19:30 Newport was reached. Carriages were taken for the Ocean House, where the party had its headquarters during the stay at Newport.

On the 26th, the Ocean Drive was taken and also the Cliff Walk. In the evening most of the party attended the concert at the Casino. On the 27th, a visit was made to Fort Adams, the Old Mill, Redwood Library, Torpedo Station and the United States Training Ship. The party left Newport at 17:15 for Boston via the Old Colony R. R., arriving at Boston at 19:50 o'clock.

This was one of the most enjoyable excursions that has been taken by the Society, the weather being delightful and nothing occurring to interfere with the enjoyment of those present.

The Committee think that there can now be no question but that all of these excursions have been of great benefit to the Society, both professionally and socially, and they trust that the custom, now well established, will be continued.

In closing, the Committee wish to thank the Members of the Society individually for their assistance in finding places of interest to visit.

E. W. Howe,
F. L. Fuller,
E. L. Brown,
Waterman Stone,
James A. Tilden,

Committee on Excursions.

REPORT OF THE COMMITTEE ON LIBRARY.

Boston, March 20, 1889.

To the Boston Society of Civil Engineers:

During the past year some 425 accessions have been made to the library, including 12 volumes of periodicals and 14 volumes of society transactions, which have been bound.

For the greater part of the year, the additions have been mostly exchanges and the United States Government reports. A few of the members, in sending out their annual reports on public works, have remembered us, but there have not been as many contributions as might be expected. Mr. Arthur D. Marble, however, has presented the society with a full set of 40 reports on the Water-Works, Spicket River Improvement and City Engineer's Department o Lawrence.

The walls of our room have received two or three new views of engineering structures and three fine portraits of the first presidents of the Society.

Through the efforts of Mr. Albert H. Howland the Society has been presented by Mrs. Philbrick with quite a number of books from the library of our late associate, Edward S. Philbrick. At her request, I had the pleasure of looking over a portion of this library and picking out all the books and pamphlets of a nature to be of value to our library. From this source we have made an addition of some 80 volumes of bound and unbound books, and about 90 pamphlets.

A new feature this year has been the donation of numerous photographs of public works, some of which have been bound in a form for safe preservation and easy reference. The question of photography is fast becoming more and more in use on works of construction, and I think it is very desirable to form as large and varied a collection of these as possible. Many of our members practice this art themselves, both on their own works and on those which they have occasion to visit. We would recommend to all to follow the example of Mr. Sidney Smith, who has presented to the Society a set of some eighty views taken by himself during the progress of the construction on the Stony Brook improvement. We can thus easily form a very valuable collection for future reference.

The loose papers of the Transactions of the Institute of Mining Engineers, which are sent out before the annual volume is published, have been sorted out and placed in binders by subjects, so as to be more convenient for perusal.

The library is fast growing beyond its present shelving capacity, and the older works have had to be stored to make room for the more recent publications. This emphasizes the importance of the work of our Committee on Permanent Quarters. We hope soon to see the day when the Society can control several rooms, with a special one for the library, where we can have some one in constant attendance; this would greatly facilitate and increase the usefulness of the collections we are now accumulating. Then it will be possible for Members who have not at their disposal proper accommodations, to deposit with the Society such books and pictures as are not in constant use, but with which they do not wish to part; they would there be at all times at the disposal of the owners, and their fellow Members could also profit by them.

The library now contains:

620 bound volumes, including 225 volumes periodicals and 133 volumes Society transactions.
902 unbound volumes and pamphlets.
15 framed views and portraits.

Respectfully submitted, H. D. Woods, Librarian,
Chairman of the Committee.

ENGINEERS' CLUB OF ST. LOUIS.

February 20, 1889:—302d Meeting—The club met at Washington University, at 8:25 P. M., Vice-President Nipher in the chair; twenty-seven Members and six visitors present. The minutes of the 301st meeting were read and approved. The Executive Committee reported the doings of its sixty-fifth meeting, recommending the following applicants for election to membership: Whitfield Farnham, E. L. Goltstein, Frank S. Ingoldsby and R. H. Phillips. They were balloted for and elected unanimously.

Proposals for membership were announced from the following parties: A. L. Johnson, Assistant Engineer of the Merchants' Bridge; Herman Krutzsch, Manager St. Louis Iron and Machine Works; Fred. E. Siebenmann, steam engineer. These were referred to the Executive Committee. The Secretary announced tha Henry Groneman, N. Johnson and E. E. Wall had qualified as members.

Mr. Russell, Chairman of the Special Committee on Closer Union of Engineering Soci ties, made a progress report asking for further time, which was granted. It was the intention of the Committee to submit an amendment to the articles of agreement among the clubs of the Association, providing for united action on such questions as might be brought before the Association. The Executive Committee also submitted a special report on transfer of membership, which was laid on the table awaiting the complete report of the Committee on Closer Union.

Professor Johnson, of the Committee on Highway Bridges, reported that in conjunction with the committee from the Kansas City Club a revised bill had been submitted to the legislature. Prof. Johnson then read a paper on "Cast Iron; Strength, Resilience, Tests and Specifications." The paper was very interesting and was illustrated by drawings and formulæ. The author had devoted a great deal of time and study to the investigation of this question and had made numerous experiments in the Washington University Testing Laboratory. He showed that the tensile strength varied from 17,000 to 38,000 pounds per square inch, and that from 20,000 to 25,000 pounds tensile strength should be required. He showed that experience did not bear out the commonly accepted theory, that the outside portion of a casting was stronger than the inside. In the author's opinion the resilience or the ability of the casting to withstand shocks was by far its most important characteristic. He showed that repeated shocks resulted in a loss of resilience and that the Heisler testing machine, which is in use in the East, was open to objection on this score. Messrs. Russell, Bouton and Wheeler took part in the discussion.

The Secretary then read a brief discussion by Wm. B. Knight of Professor Johnson's paper on cable yokes. The author gave some data from Kansas City cable roads, showing that the strength of the yokes did not affect the slot closure. In some places it had been found necessary to break the yoke in two at the bottom, which had caused no bad results. He even thought that a good road could be built without yokes. In the discussion Mr. Thos. McMath stated that at all the cable crossings of the Citizens' road, in this city, the yokes had been separated without trouble. It was also stated that this was not an unfrequent occurrence. Professor Johnson stated that the gentlemen deserved credit for the courage of their convictions, and suggested that if some one would go a step further and build a cable road without yokes it would settle the matter. Mr. Bouton stated that the continued closure of slot might be due to action of frost on the concrete tube, and the accumulation of dirt between it and the soil, which prevented its recovering its original position.

[*Adjourned.*] WM. H. BRYAN, Secretary.

MARCH 6, 1889:—303d Meeting.—The Club met in the Polytechnic Building at 8:25 P. M., thirty-one Members and five visitors present. In the absence of the President and Vice-President, the meeting was called to order by the Secretary, and Mr. Robert Moore was elected temporary chairman. The minutes of the 302d meeting were read and approved as corrected. President Meier having appeared, took the chair. An application for membership was announced from Mr. Otis Ellis Hovey, instructor in Department of Civil Engineering, Washington University, indorsed by Prof. J. B. Johnson and Mr. H. A. Wheeler. The Secretary announced that E. L. Goltstein, F. B. Ingoldsby and R. H. Phillips had qualified as Members.

Mr. Robert Moore, Chairman on the Committee on Permanent Quarters for the Club, reported that offers were under consideration from the Mercantile Library, the Public School Library and the Odd Fellows' Building. He gave an outline of the several plans. Mr. Taussig reported that the Elks Club had offered the use of their rooms. After considerable informal discussion it was suggested that it

would be well to have a meeting at each of the proposed places. It was voted to defer discussion of the matter until further notice.

Mr. Russell, Chairman of the Special Committee on Closer Union of Engineering Societies, read the following report :

"In accordance with instructions, your Committee recommends, as a preliminary step towards a closer union of the Association of Engineering Societies, that our members of the Board of Managers be instructed to submit to the Board the following amendment to the articles of association :

"Amendment 1.—In addition to his other duties, the Chairman of the Board shall act as the Chairman for the Association, and on notice from any society, through its member of the Board, that the society desires the Association to pass on any question, he shall put the question to the different societies, and receive and declare the vote. He shall also receive the reports of joint committees, and submit them to the Association. In a vote of the Association a society shall be allowed as many votes as it has members of the Board."

In favor of the adoption of this amendment by the Association, your Committee would submit the following :

"As the association of the engineering societies for the purpose of a joint publication has been so successful, it may well be considered whether its objects could not be extended with additional advantage. With the growth of these societies it has become apparent that the reading of professional papers is but one part of their work, and that there is much to be done in the line of keeping special committees at work on questions of engineering policy, or the broader questions of investigation that cannot be covered by the labor of one man. As the joint publication has done much to increase the efficiency of the societies in the one field of work, it is thought that some concert of action in the other will be equally beneficial.

"Article VI. of our articles of association reads:

"These articles may be amended by a majority vote of the Board of Managers and subsequent approval of two-thirds of the participating societies."

We cannot foresee the entire field that would be opened, nor is it necessary to state just what lines of work might be undertaken, but that we may have something definite before us, some of the objects may be suggested.

First.—In relation to engineering practice, the subject of standards furnishes a broad field for co-operative work: every-day practice brings up the inconvenience of lack of uniformity, and we see that the introduction of standards of form would be of great help to the profession. The standard screw-thread introduced by the Franklin Institute illustrates the value of work in this line. Standard units also demand attention: overlooking the much agitated question of weights and measures, there are still a number of units where a standard might be easily introduced with great convenience to the engineer. The thermal unit furnishes an instance; not to unnecessarily elaborate, we may simply state as desirable, standard tests of efficiency in engines, boilers and furnaces, standard tests of engineering materials and standard specifications. This Association is especially fitted for successful work in these lines, in that its membership is not confined to professional engineers, but includes a fair proportion of manufacturers and practical men in a number of fields.

Second.—There are a number of questions requiring a broad investigation, both on account of the nature of the subjects and that the results may have authoritative recognition, and committees representing the Association could well undertake work in this line. The work of the committee of the American Society on the preservation of timber, on tests of cement and on the relation of wheel to rail, are illustrations.

In some of these investigations we might expect to induce the government to collect much needed data. The present chief of the United States Signal Service

has already signified his willingness to adapt the work of his department to the needs of engineers, so far as he may be able.

Third.—There are times when concerted action on subjects requiring legislation is very desirable. The question of highway bridge reform in Missouri is one that is now being pushed by the Kansas City and St. Louis societies, and the force of such movements would be greatly increased by the closer association. As similar objects for the association we might instance harmony in boiler inspection, and building laws and other municipal legislation falling in the province of the engineer. The question of government works, the abatement of the smoke nuisance, and the technical education of railroad employés are also suggested.

Respectfully submitted,

S. B. RUSSELL,
J. A. SEDDON, } Committee.
J. B. JOHNSON,

Mr. Bryan moved that this report be adopted as the sense of this club. This motion being seconded, a general discussion followed, in which Professor Johnson, Robt. Moore, Professor Potter, Messrs. Russell, Bryan, Macklind, Bouton, Ferguson, Meier, Bruner and Bartlett took part. The motion was carried.

Mr. Winslow Allderdice, of Warren, O., had telegraphed that it would be impossible for him to be present. His paper on "Improving the Channel of the Mississippi" was read by Professor Johnson. Mr. Allderdice, while engaged in the naval service, was detailed for duty on the vessel "Wachusett," which attempted to make the passage up the Mississippi to St. Louis in the spring of 1879. The vessel having grounded, the manner in which she was finally floated had led the author to formulate certain suggestions as to the deepening of the channel. Maj. A. M. Miller, of the United States Engineers' Department, being present, was called on for remarks, but excused himself on the plea of not being prepared to present a discussion. The hour being late, no formal discussion of the paper was had, but Mr. Richard S. Elliott was asked to explain his plan for deepening the channel by means of water jets under high pressure, which he did at some length. Professor Johnson called attention to the success of some experiments made by the United States engineers at Horsetail Bar, with crude apparatus of a similar nature.

[*Adjourned.*] WM. H. BRYAN, Secretary.

MARCH 20, 1889:—304th Meeting.—The Club met at the Mercantile Library at 8:10 P. M., Vice-President Nipher in the chair; thirty-seven Members and two visitors present.

The minutes of the 303d meeting were read and approved. The Executive Committee reported the doings of its sixty-sixth meeting, recommending for election to membership Otis E. Hovey, A. L. Johnson and Herman Krutzsch. They were balloted for and elected.

The Secretary announced that a communication had been received asking that this Club contribute such assistance as was in its power to the special exhibition of American railroad inventions at the Paris Universal Exposition.

Professor Nipher here called Mr. Holman to the chair, and addressed the Club on "Plans of Investigations in Dynamo Designing." His remarks were illustrated by numerous drawings and by formulæ and sketches on the blackboard. He explained in detail the principles involved and showed how, when certain constants for any type of dynamo had been ascertained, the design of dynamo of the same type of any other desired capacity could be readily determined. He had recently made such a calculation for an Edison dynamo, which he used as an illustration. He gave two empirical formulæ for the safe carrying capacity of a wire in ampères. The cost of copper necessary in any dynamo and the speed at which it could be run were usually determining factors in the problem. Another important

consideration is the resistance which the space around the dynamo offers to the magnetic line. It would be very desirable to have experiments made to determine this resistance for the prominent dynamos now in the market. Messrs. Holman and Bryan took part in the discussion of this paper.

Professor Johnson then submitted a brief reply to Mr. Wm. B. Knight's discussion of the paper on Cable Yokes. Professor Johnson was not ready to admit that the strength of cable yokes was not a matter of great importance. He held that the proper way to provide resistance to the closing of the slot was by increasing the strength of the conduit, and that if the strength could be greatly increased by a new form of yoke without increase of expense, it was, in his opinion, the proper thing to do. In the discussion, Mr. Thos. McMath stated that while the slot rails of the Citizens' cable road in this city had been planed off at considerable expense, it was principally as a precautionary measure. Professor Nipher and Mr. Holman also took part in the discussion, the latter calling attention to the large amount of cable construction in prospect and the importance of this question of strength of yoke.

In the general discussion Professor Johnson called attention to a test piece of Mullens silicated iron, which in his testing machine had stood in compression 120,000 pounds per square inch. It had finally broken in the same manner as specimens of stone do. It contained a very large proportion of silica.

Mr. Holman explained a new method of making large pipe connections to water mains without interrupting the flow of water. It was available on pipes as large as 12 inches in diameter.

[*Adjourned.*] WM. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

FEBRUARY 6, 1889.—The 255th meeting of the Society was held. Past-President A. Gottlieb in the chair.

The minutes of the last meeting were read and approved.

Mr. A. D. Whitton, Mr. L. L. Wheeler and Mr. J. H. Flagg, proposed at last meeting, were elected to membership.

The resignations of Mr. A. Comstock, Joliet, Ill.; Mr. Geo. C. Morgan, Chicago, Ill.; Mr. J. F. Clarke, Toledo, O.; Mr. J. L. Gillespie, St. Paul, Minn., and Mr. Eb'n J. Ward, Marseilles, Ill., were received and accepted.

Applications for membership were filed from Edwin G. Nourse, Assistant Engineer A., T. & S. F. Railroad, Chicago; James Knox Lyons, Assistant Engineer Penna. Co., Fort Wayne, Ind.; Charles Cruft Brokaw, Bridge Engineer, Chicago, and Ricard O'Sullivan Burke, Assistant Engineer, City Hall, Chicago.

The Secretary read several communications, to which he was requested to reply.

The Committee on Highway Bridges, through Mr. C. L. Strobel, presented the following report without recommendation, and asked to be discharged :

CHICAGO, Feb. 6, 1889.

The Committee appointed to report on the best means of improving highway bridge construction, begs to report as follows :

The Committee has held several meetings, and been in correspondence with committees appointed by kindred societies. A draft of an act of legislature to promote the safety of bridges, prepared by the committee of the Engineers' Club of Kansas City, together with a memorial to the legislature of Missouri, has been received and is submitted herewith.

Your Committee has carefully considered this draft of an act, and while it is of the opinion that changes in details are desirable, and in part necessary, it recom-

mends this draft as in principle the best method yet proposed of remedying the existing evils.

The proposed act is not confined in its application to highway bridges only, but deals with railway bridges as well. There appears to be justification for this. While bridges are well cared for on most railways, they are not properly cared for on some, and an accident is much more serious in their case than in the case of highway bridges. It was thought, too, that an act dealing only with highway bridges was sure, sooner or later, to be amended by the legislature so as to include railway bridges also, in which case the amended act would probably not be as satisfactory as an act planned to apply to both types of bridges from the start.

The act does not include the appointing of a state engineer. Such an officer will, undoubtedly, be needed if the act should become a law, but it was thought advisable by the framers to ask for no legislation which would entail extra expense upon the State.

After mature consideration your Committee has concluded that it would be inopportune at this time to attempt to obtain legislation in this State, as the prospects of success are very small. Public attention has not yet been sufficiently aroused to the need of legislation of this character, and an effort on the part of engineers only will be looked upon as an attempt to furnish employment to the members of the profession, and not as a disinterested movement to secure a public good.

At some future time the necessity for legislation will, undoubtedly, become apparent to the general public, and the present preparatory work will not be wasted.

Your Committee begs to report without recommendation, and request to be discharged.

C. L. Strobel,
A. Gottlieb, Committee.
E. C. Carter,

The report was accepted and the Committee discharged.

No formal discussion was held but remarks were made by Messrs. Gottlieb and Strobel, to the effect that there was no time to present the question in the shape of a satisfactory bill at the present sitting of the legislature at Springfield, and in the shape presented by the sister societies of Missouri it would be impossible to pass it in Illinois.

Mr. Chanute explained some points in the Missouri bill.

The Committee on Standard Drawing Papers for Engineers, by Mr. Rossiter, reported progress.

The Committee on Employment, by Mr. Liljencrantz, said that as the matter had been postponed from time to time without any action it was earnestly desired that the Society should signify its intentions.

The Secretary suggested a further postponement on the score that the Society was not ready to act with due decision on the question, but Messrs. Strobel and Herr favored the work.

Mr. Herr moved that report of Committee be accepted and Committee discharged. Carried.

Mr. Herr moved that Mr. Liljencrantz be authorized to receive applications for employment and give such assistance as he can, and that a book be provided and facilities be given by the Society to carry out the work.

Mr. Lundie moved the following amendment:

That a special committee be constituted a standing committee and that such committee should make its own arrangements. All matters pertaining to employment to be turned over by the Secretary to Chairman of Committee for action.

Mr. Chanute explained the method of the American Society of Civil Engineers on a similar work which had proved a great success, it being accomplished by the use of two circulars only.

Mr. Herr spoke indorsing Mr. Chanute, but suggested that there was hardly time to carry out his plan, as something should be done at once.

Mr. Gottlieb objected to standing committee, but that Mr. Liljencrantz could do the work if he would.

Mr. Lundie's amendment was lost and Mr. Herr's original motion prevailed.

Mr. Liljencrantz accepted the action of the Society as the officer in charge of "employment."

The amendment to section 5 of the By-Laws proposed by Mr. Cooley at the last meeting was next taken up.

Mr. Strobel offered an amendment substituting $7.50 for the $5 proposed by Mr. Cooley for non-resident members.

It having been suggested that the non resident members did not receive so much value for their dues as residents, Mr. Herr said that it must be borne in mind that the onus of keeping up the status of the Society fell wholly upon the resident members, which is a matter of great importance, and to be fully considered.

The amendment to the Constitution proposed by Mr. D. C. Cregier at last meeting was next taken up, and ordered for letter ballot for next meeting.

Mr. Strobel moved to employ a stenographer for future meetings. Carried.

After some further general discussion on important points relating to the work of the Society the meeting adjourned.

John W. Weston, Secretary.

March 6, 1889:—The 256th meeting of the Society was held. In the absence of presiding officers Mr. E. C. Carter was called to the chair.

The minutes of the last meeting were read and approved.

Application for membership was made by Mr. John Sylvester Glenn.

Messrs. Edwin G. Nourse, James Knox Lyons, Chas. Cruft Brokaw and Ricard O'Sullivan Burke, proposed at last meeting, were elected to membership.

Reports of committees being in order, Mr. F. C. Rossiter, of the Committee on Standard Drawing Papers for Engineers, reported as follows:

To the Western Society of Engineers:

As one of the Committee appointed to see what could be done towards inducing manufacturers of profile and cross-section paper to furnish engineers with translucent paper for blue printing purposes, will report that by correspondence I learn that one of our manufacturers will not try the experiment under any circumstances, and the other reports that profile paper can be made on thin bond paper, but it would be expensive, stating that sheets 21 × 33 inches will cost 75 cents.

Believing that this price is exorbitant, there being no reason in my mind for charging more than the retail price for sheet profile paper, I have had experiments made for lithographing profile paper, and have succeeded beyond my expectation. The lines in this copy are too heavy, but can be reduced in the next. Blue prints taken from the bond and vellum cloth printed in blue and green inks give satisfactory results. Sample sheets are submitted herewith for inspection. My experimental sheets are only 10 × 12, but when satisfied that there will be a call for such paper I will have an engraving prepared 21 × 33, which I am satisfied I can furnish at 30 cents per sheet for bond paper and about 60 cents for vellum cloth.

Respectfully yours,

F. C. Rossiter.

Mr. Rossiter introduced some samples of profile paper which had been prepared for blue printing, and explained his experiences.

The Secretary presented some communications for action of Society and the financial report of the month.

The resignation of the Treasurer, Mr. H. W. Parkhurst, was received and accepted, and the Secretary authorized to fulfill the Treasurer's duties until further action of the Society.

Upon the question of voting on the amendment to increase the annual dues, Mr. John Lundie broadly discussed the ruling conditions, and asked for a full discussion of the subject, making the following motion:

That the vote on the increase of dues be postponed, and that a committee be appointed to consider and report at next meeting on the whole financial condition of the Society with a view toward retrenchment and reform.

A discussion followed, in which Messrs. Nagle, Liljencrantz, Lundie, Carter and the Secretary participated, and upon being put to the vote the motion was carried.

The Chairman appointed Messrs. Bates, Lundie and Liljencrantz as tellers to canvass the letter ballots on Mr. D. C. Cregier's amendment to the constitution, reported in last proceedings. They reported 68 votes cast: 56 yeas, 10 noes, 1 yes and no, and one conditional upon the members being over sixty years of age.

The Chairman appointed Messrs. S. G. Artingstall and William S. Bates as a committee to make arrangements for meeting and lunch ordered for April 3. This committee also served for January meeting, but were again appointed by vote of Society.

The question of arrangements for better and permanent quarters resulted in a motion by Mr. John Lundie:

That a committee of three be appointed to secure proper quarters for the Society and to make suggestions for keeping and conducting same. The committee to report at next meeting.

The chair appointed Messrs. Lundie, Gottlieb and FitzSimons.

The Secretary briefly called attention to the benefits to be derived from the appointment of an active committee to provide professional entertainment and matter for discussion by the Society at its regular meetings.

Mr. A. F. Nagle spoke of the Topical Questions which had afforded much experience to the American Society of Mechanical Engineers, and coincided with the views of the Secretary.

Mr. Carter called attention to the actual work of the Western Society of Engineers not being adequate to its condition, indorsed the proposition, and urged that the matter should be brought up at the next meeting.

Mr. Wm. S. Bates moved that a plan be formulated to provide papers and discussions at next meeting. Carried.

As the hour was late the paper "On the Croton Valley Storage," by Samuel McElroy, was ordered to be read at next meeting.

After discussing the hour of meeting, whether it could be changed to an earlier one to the advantage of the majority, the meeting adjourned to meet at 5 P. M. April 3.

JOHN W. WESTON, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

NOVEMBER 13, 1888:—The meeting was called to order by President Whitelaw at 8:20 P. M.; 14 Members were present at opening.

The minutes of the last meeting were read by the Secretary, and approved.

Mr. J. H. Sargent read a paper that he had prepared with regard to the death of Mr. A. C. Getchell. Mr. N. P. Bowler stated that he had promised to assist Mr. Sargent in preparing suitable resolutions and notice of Mr. Getchell's life, but that he had been suddenly called away, and had been unable to do anything in the matter. The Committee asked for an extension of time, which was granted.

The Secretary stated that a pamphlet respecting the Westinghouse Electric Company had been presented to the Club by Mr. Chas. Paine.

As there was no other business before the Club, Mr. N. S. Possons, Superintendent of the Brush Electric Light Works, read his paper on "Recent Applications of Electricity."

After discussion on Mr. Possons' paper, the meeting was adjourned till the second Tuesday in December.

JAMES RITCHIE, Secretary.

ANNUAL MEETING.

MARCH 12, 1889:—President Whitelaw in the chair; 14 Members present; meeting called to order at 8:15 P. M.

The minutes of the last meeting were read by the Secretary and approved.

Mr. C. P. Leland, Chairman, made his report on behalf of the Committee on Banquet.

Mr. James Ritchie read the reports of the Executive Board, the Treasurer and the Librarian.

Mr. Leland moved that the reports be received and placed on record. The motion was seconded by Mr. Searles and carried.

The chair appointed Messrs. Augustus Mordecai and C. W. Paine tellers to count the ballots for officers.

Mr. Mordecai reported that the following ticket had been elected: President, W. R. Warner; Vice-President, H. C. Thompson; Treasurer, S. J. Baker; Secretary, James Ritchie; Corresponding Secretary, A. H. Porter; Librarian, J. L. Gobeille; Member Board of Managers, W. H. Searles.

Mr. Mordecai moved a vote of thanks to the retiring officers for the able and efficient manner in which they had performed their duties. The motion was seconded by Mr. Leland and carried.

Mr. Whitelaw read a letter from Mr. Newton Anderson tendering his resignation from membership. The letter was referred to the Executive Board.

[*Adjourned.*] JAMES RITCHIE, Secretary.

REPORT OF THE EXECUTIVE BOARD.

The officers of the Civil Engineers' Club of Cleveland, constituting the Executive Board, respectfully submit their annual report.

There have been held sixteen meetings of the Club during the year (besides the annual banquet at the Hollenden on March 20, 1888). The average attendance has been 14 at the regular meetings.

The membership of the Club at present consists of 4 Honorary, 105 Active, 5 Corresponding and 4 Associate Members. There have been elected during the year four Active and one Corresponding Member, and one Member was changed from the Active to the Corresponding list. Two of our Active Members, Mr. Charles Latimer and Mr. A. C. Getchell, have died during the year.

The following papers have been presented: Asphalt and Stone Pavements, by Mr. Torrey (not a member); Cable Railroads, by Mr. John Walker; West Point Tunnel, by Mr. Wm. H. Searles; Progress in Civil Engineering, by Mr. Walter P. Rice; Recent Applications of Electricity, by Mr. N. S. Possons; Progress in Railroad Engineering, by Mr. H. C. Thompson; Construction of the Arcade Building, by Mr. John Eisenmann; New Discoveries in regard to Light, by Prof. E. W. Morley.

Several of these have already appeared in the JOURNAL of the Association, and others are in course of publication. Some of them, however, we regret to say, have not been furnished to the Committee for publication after reading. The JOURNAL is published monthly under contract by the *Railroad Gazette*, at the same rates as heretofore, and a copy is regularly mailed to every Member.

There are twenty-six periodicals furnished for the club room tables. A portion are sent to us free, and the remainder are supplied by the Case Library Association from the seventy-five dollars rental paid by the Club.

The Club library is still in a semi-chaotic condition for want of shelf room to properly arrange and classify the books and pamphlets. The Club is indebted to Col. John M. Wilson, Honorary Member and past President of the Club, for frequent donations of valuable public documents.

The Treasurer reports the receipts for the year, including cash on hand March 13, 1888, at $799.58 ; expenditures, $783.25 : leaving a balance in the treasury this date of $16.33. Amount of membership dues remaining unpaid this date, $63.

The annual banquet of the Club was held at the Kennard House on March 14. Seventy-five gentlemen sat down to an elaborate menu. According to the usual custom of the Club no wine was served. After listening to a number of interesting speeches and spending a social evening the Club adjourned.

JAMES RITCHIE, Secretary.

MINNEAPOLIS SOCIETY OF CIVIL ENGINEERS.

JANUARY 2, 1889:—A regular meeting was held, President Pike in the chair. Minutes read and approved.

Resignations of Messrs. J. E. Turner and H. M. White were accepted. Mr. J. E. Howe was elected to membership.

An amendment to Article 12, making the annual dues $5 and initiation fee $10, was adopted. In the semi-annual reports of officers, Professor Pike thought the Society in shape to do good, earnest work, and urged the early securing of permanent rooms, where the Society might have its library and enjoy many other privileges which can be found only in a home.

W. W. Redfield was appointed to audit the Treasurer's accounts for the past year.

The election of officers for 1889 resulted as follows:

President—Prof. Wm. A. Pike.

First Vice-President—Geo. W. Sublette.

Second Vice-President—L. C. Deterly.

Secretary—Prof. W. R. Hoag.

Second Secretary and Treasurer—C. A. Huntress.

Librarian—W. W. Redfield.

Member of Board of Engineering Societies—Wm. De Le Barre.

The Society gave a vote of thanks to the retiring Secretary, Walter S. Pardee, for his long and earnest service.

President Pike's paper on "The Quaker Bridge Dam" was a comprehensive review of all the leading features of the dam, together with a discussion of a few of the more perplexing problems connected with it.

The Society gave a vote of thanks and ordered it printed in the JOURNAL.

Professor Hoag read a paper on "Solar Attachments." The latter part of his paper, relating to "Solar Transit Surveying," by the use of a solar of his own design, was not reached, and it was voted to continue it at next meeting.

[*Adjourned.*] W. R. HOAG, Secretary.

FEBRUARY 6, 1889:—A regular meeting was held, Prof. Pike in the chair. The minutes were read and approved.

After several letters of communication were read from secretaries of other so-

cieties, relative to correspondence and transfer of members from one society to another during temporary absence, the literary programme was taken up.

This included a paper by Prof. Hoag on Solar Attachments, in which he pointed out the defects of the more common attachments, dwelling on Smith's Solar in particular, offering a design of his own which seemed to correct these faults.

G. W. Sublette's paper on Subdivision of the Section cleared up all the problems the County Surveyor is liable to meet in establishing sixteenth corners or reproducing last section or quarter corners.

The paper called out considerable discussion.

[*Adjourned.*] W. R. Hoag, Secretary.

March 6, 1889:—Meeting called to order. First Vice-President Sublette in the chair. Minutes of last meeting read and approved. Letters of communication from James Rigby and New England Water-Works, containing a programme of their spring work, were read.

The literary programme for the evening consisted of a very interesting paper on "Permanent Improvement of Highway," by G. E. Crary. A lengthy discussion followed, branching into the various forms and relative merits of street pavements.

[*Adjourned.*] W. R. Hoag, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

March 4, 1889:—Regular meeting of the Society held at Hotel Ryan, eleven Members present.

The minutes of the last meeting having been approved, the Committee upon Interchange of Members between the different engineering societies reported in favor of a plan of this kind, provided the other societies united in the plan. The Committee was continued with instructions to correspond with other societies on the subject.

The Committee upon Membership reported progress and was continued.

The report of the Committee upon Bridge Legislation was read and also the act as proposed by the Engineers' Club of Kansas City now before the Missouri Legislature. The desirability of legislation and what it should be was then discussed by those present. Mr. Horton stated that in his opinion to regulate the construction of bridges by law would result in the erection of bridges unnecessarily strong for many country towns, and such places would be unable to build bridges on account of greatly increased cost. In his opinion the taxpayer should be considered. The bridges erected by most towns at present were ample to carry the usual loads brought upon such structures and the percentage of accidents was very small, so small as to be hardly worth notice.

Mr. Osborne expressed as his opinion that legislation was not needed to force railroad companies to build safe bridges, as it was so greatly for the interests of each company to look after its own structures.

Mr. Loweth remarked that while both railroad and highway bridges might be improved thorough inspection by a skilled engineer, and cited cases in this State where a railroad company had absolutely no plans at all of some of the bridges on its line, yet the present was not a good time to crowd further legislation upon railroads. Some good would be obtained by having the plans of all bridges filed with the strain sheets, etc., at the capital of the State.

Other remarks were made by Messrs. Rockwell, Münster and Mason.

The general feeling, as expressed by the speakers, was, on the whole, rather against legislative enactments, but in favor of compelling plans and strain sheets to be filed where accessible to the public, and that the parties building bridges,

either railroads or towns, should be held strictly responsible for the safety of the structure, and liable for any damages sustained in case of accidents.

The Secretary was empowered to have a list of the Members printed, and the name of Mr. Karl L. Lehman was presented as an applicant for membership in the Society.

[*Adjourned.*] GEO. L. WILSON, Secy.

ENGINEERS' CLUB OF KANSAS CITY.

MARCH 4, 1889:—A regular meeting was held in the club room at 8 P. M. President O. B. Gunn in the chair, Kenneth Allen, Secretary. There were present eleven Members and three visitors.

Minutes of the last regular meeting and that of the Executive Committee were read and approved.

On canvass of ballots, John E. Thomes. Waterman Stone, J. B. Chapman, F. E. Sickels, E. A. Harper, R. H. Elliott and L. B. Root were declared elected as Members.

Mr. Breithaupt reported progress on the question of Bridge Reform. Mr. Chanute, Professor Johnson and Mr. Breithaupt had each gone to Jefferson City, representing the St. Louis and Kansas City societies.

It was found that: "*First*, Railway bridges are already provided for by the Railway Act, thus leaving the ground free for an act concerning county bridges. *Second*, The counties are dissatisfied with the present law concerning the *letting* of county bridges, and would be glad to have a better one. This will give a good starting point to provide for the erection of good bridges. *Third*, There is great jealousy of any interference with the autonomy of the counties."

The bill has accordingly been revised to meet the requirements of the case and returned to the sub-committee, to whom it was referred by the Legislature.

The Western Society, while indorsing the essential features of the bill, advise no action at present in Illinois.

Mr. Mason reported, for the Committee on Transfer of Members, that copies of the constitution of the various societies had been received and were being looked over before the proposal of any scheme.

Mr. C. E. Taylor read a paper on "Strengthening Iron Railway Bridges." In bridges considered, trusses found strong enough, while floor and lateral systems were too light for modern traffic. The lightest beam had web $\frac{1}{4}$ inch × 15 inches and length of 14 feet 6 inches. Bridge panels 15 feet.

All beams removed and replaced by new ones of about 50 per cent. greater section, but, with one exception, of same general dimensions as those removed.

Owing to the manner in which end beams were connected to truss, it was necessary to disconnect half the lower chord at this point while changing the beams. This was done by relieving chord-bars of tension in end two panels by means of heavy tackle.

Changing intermediate beams was somewhat simpler, but required the spreading apart of the bottoms of trusses, to disengage beams from posts, in which they were inserted about 6 inches.

Another interesting feature of the improvement of these bridges was the changing of several cracked stone pedestal blocks—the corners of the bridges at these points being lifted about $1\frac{1}{2}$ inches by means of two 20-ton hydraulic jacks and a special bracket attached to end post.

The paper was discussed by Mr. Goldmark.

Mr. R. L. McAlpine was proposed as Associate Member by Wynkoop Kiersted and Kenneth Allen.

[*Adjourned.*] KENNETH ALLEN, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

SECOND ANNUAL MEETING.

First Session.

JANUARY 19, 1889:—The first session of the annual meeting was held at the office of Mr. E. H. Beckler, Chief Engineer of the Montana Central Railway, at 8 P. M., Col. W. W. de Lacy, chairman. There were 12 Members present.

Minutes of previous meeting were read and approved.

Mr. Fk. L. Sizer was re-elected a charter member. Messrs. J. R. De Witt, Jr., and C. S. Haire were elected Members.

Applications for admission were read from Fk. A. Ross, Jas. MacFarlane and Leopold O. Danse. Ordered filed, and letter ballots to be issued.

The Committee on Memorial to the Legislature, praying for the establishment of suitable remuneration for expert testimony, made a verbal report. Further consideration deferred until next regular meeting.

The Secretary reported the action of meeting of March 17, 1888, referring the "question as to the best manner of securing papers and discussions to the next annual meeting." Further consideration deferred until session of 21st inst.

A communication from the Engineers' Club of Kansas City relative to entering an alliance of engineering societies for the transfer of members, was referred to a special committee consisting of Messrs. Cumming, Kelley and Kemna.

The Committee on Arrangements for the annual meeting reported the following programme as having been arranged for the exercises at Butte:

Helena members and guests will arrive in Butte 21st inst. on Montana Central train, due 11:20 A. M., to be joined at the depot by the Butte members and guests.

The party will then proceed to the Montana Union depot, where a train will be in waiting to convey them to Anaconda, arriving at about 12:45 P. M.

The afternoon will be spent in examining the smelters and reduction works of the Anaconda Smelting Company, returning to Butte on train leaving at 6 P. M.

Half an hour after arrival in Butte, members will convene for the transaction of business and discussion of papers.

At 10 P. M. sharp, the Society and invited guests will assemble at the Metropolitan Restaurant, Park Street, to partake of the Annual Banquet.

For the entertainment of those who may wish to remain over, excursions have been arranged to points of interest in the city and vicinity.

The canvass of letter ballots received for officers for 1889 showed the following to be elected:

Benjamin H. Greene, President.
Elbridge H. Beckler, First Vice-President.
Henry B. Davis, Second Vice-President.
James S. Keerl, Secretary and Librarian.
Charles W. Helmick, Treasurer.
Thomas T. Baker, Trustee for three years.

Meeting adjourned to meet at call of the President.

Second Session.

JANUARY 21, 1889:—Fourteen Members and three guests boarded the 8:25 A. M. train of the Montana Central Railway bound for Butte.

The ride to Butte was a most interesting one to our party, abounding, as it does, at every turn, with those features not alone entertaining to the engineer, but to the lover of grand and imposing scenery.

The enjoyment of the party was greatly added to by the possession of a handsomely executed map and profile of the line traversed, loaned through the kindness of Mr. John Herron, Acting Chief Engineer of Montana Central Railway,

which recorded the maximum grade as 2.2 feet per 100 an curvature 10 degrees, distance from Helena to Butte 73.3 miles, with five tunnels of total length 9,052 feet, the Wickes tunnel being 6,112 feet long. The substantial character of the construction could not but impress itself upon the travelers. The rail used is 75 pounds, with oak ties on the curves, transported from Minnesota.

The road crosses two divides, first, from the Missouri to the Boulder; second, from the Boulder to the Deer Lodge.

At the Helena Depot the elevation above sea level is 4,000 feet, at the first named divide (Wickes tunnel) 5,454 feet, at the Continental Divide, 8 miles from Butte, 6,350 feet and at Butte Depot 5,500 feet. The appointments of this new road proved first class in every particular and drew from the pioneers of the party many humorous comparisons as between the present system of conveyance and that in vogue when last they traversed the same route upon the back (sometimes) of a bucking "Kiyus." The run from Helena to Butte is made in 2 hours and 55 minutes. At several points along the line a speed of 50 miles an hour was observed. Reaching Butte on schedule time the Helena contingent was received by the following Butte members:

Messrs. Harper, Wilson, Knight and Gillie, accompanied by Messrs. C. W. Goodale and H. Williams, our guests from Butte, who conveyed us immediately on the motor line to the Montana Union Depot, where we found the train had been held awaiting our arrival through the courtesy of Supt. G. W. Dickinson, who forwarded us at once to Anaconda. Upon reaching the Smelter City we were received by Manager Daly, Superintendent Stalmann, and Messrs. Raup, Durstan and Webb, all of the Anaconda Company, who welcomed us to the Swansea of the West. We were first invited to make an examination of the lunch awaiting us at A. M. Walker's boarding-house at Carroll, to which, our appetite being sharpened by our ride, we did ample justice. We were next escorted over the immense works of the Anaconda Company, and with the greatest unreserve shown every detail of the gigantic business. The favor shown our party was an unusual one, and we fully appreciated the distinguished courtesy extended by Mr. Daly. The entire afternoon was spent in examining the upper and lower works, which to describe in a manner sufficient to give one an adequate conception of their immense proportions—which to some might be an easy task—the writer must confess to his inability, through a want of fitting words. At 5:45 P. M. we returned to Butte highly delighted and instructed by the marvels we had seen. In that visit we received a better impression of the immensity of the industries sustained by the output of the Butte mines than a week spent in examining the mines themselves.

At 8 P. M., a meeting was held in the Probate Court room at the Butte Court House, President Geo. K. Reeder presiding.

There were present 19 Members and four visitors. On motion, carried, the reading of the minutes of previous meeting was dispensed with.

The "question as to the best manner of securing papers and discussions" was presented as unfinished business from the last meeting. After discussion, Mr. Foss made the following motion, carried: "That a new Committee on Topics be appointed for the ensuing year, at the next regular meeting of the Society." Mr. Herron made the following motion, carried: "That any person who was elected a charter member of this Society, and who received a unanimous vote for re-election, may become a charter member by paying all back dues."

Moved and carried unanimously, "That a committee of four be appointed to draught suitable resolutions, expressing the high appreciation of this Society for courtesies extended by the railroads and other companies, also individuals, upon the occasion of their second annual meeting."

Committee appointed, Messrs. Knight, Greene, Herron and Reeder.

The Secretary and Librarian presented and read his report for the past year.

Upon motion, carried, it was received and referred, together with his books of accounts, to the Board of Trustees for auditing and report.

To the President and Members of the Montana Society of Civil Engineers:

GENTLEMEN: I have the honor to submit my report as Secretary and Librarian of your Society, covering the period since my last report, dated January 21, 1888, to this 19th day of January, 1889.

During this period the amounts paid to me as Secretary have been as follows:

February 18, 1888.—Balance paid by Chairman of Committee of Arrangements upon banquet tendered by the resident members of Helena to the M. S. C. E. January 21, 1888. (This amount stands to the credit of the Helena members, as per instructions of meeting held February 18, 1888)	$14.85
Initiation fees received from ten members at, $5	50.00
Semi-annual dues for first half of 1888, received from 45 members, at $2.50	112.50
" " " second " " " 40 " " " "	100.00
" " " first " 1889, " " 3 " " " "	7.50
Assessment on account of expenses of Executive Board of the Council of Engineering Societies on National Public Works, at $1 per member, received from 44 members	44.00
Total receipts	$328.85

This amount has been paid to your Treasurer, John W. Wade, Esq., vouchers for same being hereto attached.

Expenditures.

Orders have been drawn on the Treasurer covering the following distribution:

For printing and stationery	$101.40
For subscription to "Proceedings of American Society of Civil Engineers"	10.00
For engrossing resolutions passed to J. T. Dodge, past president	5.00
For incidental expense account of Secretary	21.35
For assessment account Association of Engineering Societies	112.00
For donation to Executive Board of Council of Engineering Societies on Nat. Pub. Wks	50.00
Total expenditures	$299.75

Leaving a balance in the treasury of $192.55.

Dues Uncollected

6 Members are delinquent in dues for the year 1888, at $5	$30.00
6 " " " " " " " half year 1888, at $2.50	15.00
6 " " " on assessment account Executive Board of Council of Engineering Societies National Public Works at $1	6.00
48 Members are delinquent on dues for first half of 1889, at $2.50	120.00
Total dues uncollected	$171.00
Balance in treasury	192.55
Making assets	$363.55

All bills presented have been paid excepting two amounting to $3, one from the Independent Publishing Company for $1.25, received too late for being included in this report, and one for like amount from the publishers of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, which they are to include in their bill for the set of back volumes of the JOURNAL.

I would most respectfully call your attention to Section 6, Art IV., of the By-Laws, requiring the collection of semi-annual dues, and would suggest looking to avoiding what I believe to be an annoyance to the members, as well as what would appear a needless duplication of clerical work on the Secretary, that this section be so amended that the annual dues may be collected by one payment.

There are now upon on the Roll of Membership 51 Active and 1 Associate Members, 10 Members having been added to the Roll since my report of January 21, 1888. Two gentlemen are now under ballot for membership and 4 applications for membership I have in hand. For a statement of the Transactions of the Society, I would respectfully refer to the minutes I have been keeping of the same. My books of accounts are herewith presented for examination and auditing by the Board of Trustees, as provided by the By-Laws.

As Librarian of your Society I greatly regret I have little to report. While the Society has ordered the purchase of the back volumes of the JOURNAL OF THE

ASSOCIATION OF ENGINEERING SOCIETIES, there has been some trouble experienced on the part of the publishers in securing all the numbers. If any member has the first volume and No. 4 of Vol. VI., or the whole of Vol. VI., which he is willing to part with, I should be glad to enter into negotiations with him looking to their purchase.

The Transactions of the American Society of Civil Engineers for 1888 have been added to the Library during the year as received.

I have received the following general publications during the year for the library:

Constititution and By-Laws, Boston Society of Civil Engineers for 1888.

Proceedings National Association of Builders 1888, with Standard Specifications for Architects.

Proceedings of the Indiana Society of Civil Engineers and Surveyors' 8th Annual Meeting, 1888.

Pamphlet of the Westinghouse Electric Company, descriptive of the Alternating System.

The Technic, University of Michigan, 1888.

In view of the present condition of the library and of its great importance to a society of this character, especially when we call to mind our isolated position—with no library within a thousand miles at all adapted to our needs—to say nothing of our expectations, I would consider it a neglect of duty should I fail to call your attention to this matter, and earnestly request that such means be adopted, as to you may seem best, looking to building up an engineering library, so invaluable to the engineer and a potent factor in keeping alive his interest in the Society.

We can, I believe, safely count upon a membership at the close of this year of 60. Should we make an assessment of $3.00 per Member for a library fund, this would secure $180 in books, etc., the library could be made a circulating one, giving every member its full advantages at a tax none of us would feel, and in a few years be in posseesion of that most valuable auxiliary to the engineer—a first-class library, which, were he ever wealtny enough to have secured, would probably now be found in sections between the Florida Keys and Alaska.

Your obedient servant, J. S. KEERL,

HELENA, Mont., Jan'y 19, 1889. Secretary and Librarian.

Discussion ensued upon the recommendations contained in the Report of the Librarian. Mr. John Herron called the attention of the meeting to the desirability of establishing headquarters for the Society, and made the following motion, carried unanimously: "That a Committee of three be appointed to report upon the questions of a Library and permanent headquarters for the Society, to report at next regular meeting."

Committee appointed, Messrs. Herron, Gillie and Harper.

President George K. Reeder made his annual address upon the engineering progress during the preceding year, his theme being the "Panama Canal."

The chair announced the election of Gen. B. H. Greene to the Presidency of of the Society for the ensuing year and inducted him into office. Upon taking the chair Gen. Greene addressed the meeting and assured the Society of his high appreciation of the honor conferred upon him.

The reading of the papers prepared for this session was deferred until a future meeting—the hour being near to 10 o'clock, the time set for the Annual Banquet.

Meeting adjourned to meet at the call of the President.

SECOND ANNUAL BANQUET.

Nineteen Members, with fourteen guests, assembled at the Metropolitan restaurant. After a few "preliminaries," a "final location" was made of ten elegant courses, which called for unparalleled feats of gastronomy.

Mr. Elliott H. Wilson, of Butte, acted as toast-master. The following is a list of the toasts:

"The Montana Society of Civil Engineers." Response by H. B. Davis, Second Vice President Montana Society Civil Engineers.

"The Press." Response by Fk. M. Leonard, of the Butte *Inter-Mountain.*

"The Pioneer of Civilization—The Engineer." Response by W. W. de Lacy, Chief Clerk Surveyor General's Office, Montana.

"Our Wives and Sweethearts." Responses by A. E. Cumming, C. W. Goodale and J. R De Witt, Jr.

"Mines and Miners." Response by A. B. Knight, Engineer Blue Bird Mine.

"National Public Works." Response by J. H. Ellison, Assistant Engineer, Montana Central Railway.

"Engineering Societies, the Exponents of Our Profession." Response by J. S. Keerl, Civil Engineer, East Helena Smelter.

"Territory of Helena." Response by W. F. Parker.

"The Railroad Engineer." Response by John Herron, Principal Assistant Engineeer Montana Central Railway.

"Mineral Locations and Surveys." Response by Jos. H. Harper, City Engineer, of Butte, M. T.

"Territory of Butte." Response by Geo. H. Irvin II., President Amy & Silversmith Mining Company.

"Municipal Engineering." Response by G. N. Miller, Superintendent Sewer Department, Helena, M. T.

"Our Western Railroads." Response by J. W. Kendrick, Chief Engineer Northern Pacific Railroad.

"Our Guests." Response by Frank L. Sizer, Civil Engineer.

Followed by "Auld Lang Syne," at 3 A. M.

Third Session.

JANUARY 22, 1889:—The Members divided themselves into groups, visiting during the day several mines and smelters in Butte. Supt. C. W. Goodale, of the Gagnon mine, kindly piloted a party of six through the underground workings of that property for nearly two hours.

Another party visited the mines of the Anaconda Company, chiefly with the view of examining the hoisting engines—especially that at the Mountain View mine, which possesses several novel features. They also visited the Parrott Smelter.

A 5 P. M. a meeting was held at the office of Baker & Harper, President B. H. Greene presiding. There were 10 Members present and 3 visitors.

A paper upon "County Records" was read by Mr. Geo. O. Foss. After some discussion, Mr. A. B. Knight made the following motion, which was carried unanimously: "That a Committee of five be appointed to consider the recommendations presented by the paper of Mr. Foss and report at some special meeting to be called at as early a date as possible, and recommend what action, if any, should be taken by this Society to bring the matter before the Legislature in proper form." Committee appointed, Messrs. Foss, Knight, de Lacy, Reeder and Harper.

The following amendment to Section 1, Article 1, of the Constitution, was submitted by Mr. A. B. Knight, and seconded unanimously, "That Sec. 1, Art. 1, be made to read as follows:

"'*The name of this Association shall be the Montana Society of Engineers.*'"

In explanation of the amendment proposed Mr. Knight stated in effect that some had thought an inconsistency existed between the name of the Society and its qualifications for membership, which made eligible those in all of the collateral professions, and that the objects of the Society would probably be promoted by the change indicated.

Meeting adjourned to meet February 16, 1889, at 7:30 P. M., at Helena, Mont.

J. S. KEERL, Secretary.

FEBRUARY 11, 1889:—Pursuant to a call issued by the President, the 7th inst., a *special meeting* was held at 8 P. M. at the office of Mr. E. H. Beckler, Chief Engineer M. C. Railway, President B. H. Greene in the chair. There were present 18 Members aud two visitors.

The Committee to whom the paper by Mr. George O. Foss upon "County Records" was referred at the previous meeting, made a verbal report, submitting a bill for presentation to the Legislature looking to the enactment of laws designed to overcome the present objectionable manner of keeping county records. The bill was read by Mr. Foss and was discussed at length, following the motion made by Mr. Sizer, viz., "That the report of Committee, in so far as it relates to the bill presented governing town plats and plats of additions, be adopted with the earnest indorsement of the Society, and the Committee or such sub-committee as the Chair may appoint be directed to present this bill to the proper House Committee of the Legislature for action, urging its passage."

The discussion resulted in amending the bill in several particulars.

Upon the presentation of the bill as amended, it was moved by Mr. Sizer and carried. "That the bill as amended be adopted with the earnest indorsement of this Society, and that a Committee of three be appointed by the Chair to present the same to the proper committee of the Legislature, urging its passage. Where upon the Chair appointed as such Committee Messrs. Foss, Harper and Knight.

The following is a copy of said bill as printed for the council:

SECTION 1. That Sections 2031, 2032, 2033, 2034, 2037 and 2038 of the Fifth Division of the Compiled Statutes of Montana be amended so as to read as follows:

§ 2031. Whenever any city, town or village shall be laid out, the proprietor or proprietors of the city, town or village or additions laid out, shall cause to be made an accurate plat or map thereof, setting forth:

1. All streets, alleys, avenues and highways and the width thereof.

2. All parks, squares and all other ground reserved for public uses, with the boundaries and dimensions thereof.

3. All lots and blocks, with their boundaries, designating such lots and blocks by numbers, and giving all the dimensions of every lot and block so designated. Also showing the angles of intersection of all boundary lines of such lots and blocks, whenever such angle of intersection is not a right angle. Also the location of all stone or iron monuments set to establish street lines; also the exterior boundaries of the piece of land so platted, giving such boundaries by true courses and distances; also the exact location of all section corners, or legal subdivision corners of sections within the limits of said plat; and the adjoining block corners of all surveyed and adjoining additions.

In case no such section or subdivision corners are within the limits of the plat, it shall show a connection line to some corner or inital point of the Government surveys, if there be any such within one mile of such town site. All distances marked on said plat shall be in feet and decimals of a foot.

An accurate survey of such town or village site or addition shall be made by a competent surveyor, who shall mark all the corners of the lots and blocks so laid out and shown on the plat, by substantial stakes or monuments. He shall set stone or iron monuments at the points of intersection of the centre lines of all streets where practicable. If not practicable to set such monuments at the points of intersection of said streets, they shall be set as near such point as possible, and their location shall be shown by marking on said plat the distances to the block corners adjacent thereto. The top of such monuments to be placed one foot below the surface of the ground, and the monuments shall be at least six inches by six inches, by one foot in depth. If a stone is used it shall have a cross cut in the top at the point of intersection of the street lines, or a hole may be drilled in the stone to mark such point. Iron monuments should be at least three-quarters of an inch in diameter by one foot in length. The dimensions of such monuments to be marked on the plat. Such monuments shall establish permanently the lines of all streets.

The surveyor shall also make and subscribe on said plat a certificate that he has made such survey and plat according to the provisions of this act, stating the date of such survey. And he shall make oath thereto before some officer authorized to administer oaths.

§ 2032. The proprietors of the land so platted, or their attorneys, duly authorized, shall make on such plat a certificate to be known as the Certificate of Dedication, which shall be substantially in the form following, viz.:

We....................do hereby certify that we have caused to be surveyed,

subdivided and platted into lots, blocks, streets and alleys, as shown by the plat and Certificate of Survey hereunto annexed, the following described tract of land, to-wit: (Here describe land included in plat) to be known and designated as (here give full name of town, village or addition) and the lands included in all streets, avenues and alleys and parks or public squares shown on said plat, are hereby granted and donated to the use of the public forever.

Dated this..........day of..................A. D........

This Certificate of Dedication shall be signed by all the proprietors of the land included in the plat, and by all persons holding mortgages thereon, and shall be acknowledged by them in the same manner as required by law to entitle deeds to be recorded.

§ 2033. All such plats of lands in or adjoining any incorporated city or town, shall be examined and approved by the Council or Board in which the municipal authority of such corporation is invested, and a copy of such plat shall be filed with the Clerk of such corporation. A certificate of such approval, signed by the City or Town Clerk, and also the certificate of the City Engineer of such city or town, if there be one, that the plat conforms to adjoining additions or parts of the city or town already platted, as near as the configuration of the ground will admit, shall be written on such plat before the same shall be filed in the Recorder's office of such county.

The plats of additions to unincorporated cities or towns shall be referred to the County Commissioners of the county in which such additions are situated, who shall examine them and see that they conform to the parts of the city or town already platted, and who shall then, if they find the plats correct, attach their approval thereto.

§ 2034. All plats of cities, towns or villages, or additions thereto, shall be made on mounted drawing paper and filed and recorded in the office of the Recorder of the county in which the lands are situated.

Before filing the same, the Recorder shall examine such plat and see that all the requirements of this Act in regard thereto have been complied with.

The Recorder shall provide, at the expense of the county, a well-bound book of mounted drawing paper, and of a convenient size for public use, to be designated "Plat Book No....," in which he shall make a true copy of every plat filed by him under this Act, and of all certificates thereon (except that the scale and size of the plat may be changed to fit the book), and shall certify to the correctness of such copy, which book shall be a public record, and he shall safely keep the original plat for inspection only, to test the accuracy and genuineness of such copy.

For filing and recording such plat, the Recorder shall receive as fees, the sum of twenty-five cents for each lot or subdivision shown thereon to the number of one hundred, and fifteen cents for each lot shown thereon in excess of one hundred, *Provided*, that for recording any such plat showing less than forty lots or subdivisions, he shall receive the sum of ten dollars, and that the fee for recording any plats shall not exceed one hundred dollars.

§ 2037. The Recorder of each county in this Territory is hereby authorized and required, within one year from the date of the passage of this Act, to provide suitable Plat Books of mounted drawing paper, and to cause to be copied in such books, all plats of cities, towns and additions thereto, and all subdivision plats of land in his county with the certificates thereon, or attach to said plats, and to certify to the same, as provided in this Act for plats hereafter to be filed, and shall receive the same fees as provided in this Act, for recording such plats, which fee shall be paid out of the County Treasury, and all original plats in his office shall be safely kept by the Recorder, for inspection only.

§ 2038. Such plat must be recorded before any lots or blocks are sold or transferred by deed or contract, or leased, and the proprietor or proprietors of any city, town or village site or addition, or any part thereof, shall forfeit or pay for each lot so sold, transferred or leased, a penalty of not less than ten dollars nor more than one hundred dollars. Such penalty may be recovered in a suit brought in the name of the people of the Territory of Montana against such person or persons so offending, and such penalty, when recovered, shall be paid into the County Treasury of the county wherein said premises are situated, for the benefit of the common school fund.

Any person or persons who shall wilfully or knowingly destroy any stake, stone or monument placed by any surveyor in this Territory, shall be deemed guilty of a misdemeanor, and upon conviction thereof, shall be fined not less than ten dollars, nor more than one hundred dollars for each and every stake, stone or monument so destroyed, which fine shall be paid into the county treasury in the county in which the offense was committed, for the benefit of the common school fund.

§ 2. All laws or parts of laws in conflict herewith, are hereby repealed.

The President announced the receipt by him of a communication from Mr. Geo. H. Robinson, calling attention to greatly needed legislation, looking to improving

the laws affecting mineral locations and suggesting an outline of features to be covered. The subject matter was a copy of a letter written to the Hon. Joseph Davis, Member of the Legislature. The President stated that he had handed the communication to the Committee having under consideration the paper upon County Records, with request that they make such recommendations upon the same to this meeting as to them might appear proper.

Mr. Foss, Chairman of the Committee, read the communication and reported that the Committee had examined into the subject and would recommend the adoption in the main of the law of Colorado upon the question, with some amendments, all of which were submitted.

Mr. Sizer moved, "That the matter of mineral law, as reported by the Committee, be placed under discussion and acted upon section by section." Carried.

Mr. Foss read the report, embodying the laws proposed, each section being discussed. Amendments to same were moved and carried. During discussion a motion, made for a recess of ten minutes, was lost.

After further discussion upon said report, the following motion prevailed :

"That Committee now reporting be instructed to draw up a complete bill, embodying the views of this meeting upon the laws that should be made by the Montana Legislature affecting mineral locations, and to report at an adjourned meeting to be held to-morrow evening.

[*Adjourned.*] J. S. KEERL, Secretary.

FEBRUARY 12, 1889:—Pursuant to adjournment of 11th inst., a meeting was held at 8 P. M. at the office of Mr. Beckler. Mr. A. B. Knight, of Butte, was elected chairman. There were present 12 Members and one visitor. The reading of minutes of previous meeting was dispensed with.

The Committee having in charge the framing of a bill affecting mineral local tions made a verbal report, and submitted the bill which they had prepared.

The bill was considered section by section, resulting in several amendments being made. Upon the Committee presenting the bill as amended, Mr. Foss moved its adoption by the Society. Mr. Keerl moved to amend by referring bill to an attorney for his opinion, touching the consistency of its provisions with the United States laws.

Considerable discussion was had upon this amendment to the motion, it being held by those in its favor that the bill affected materially the mining interests of the territory and would doubtless receive severe criticism from those affected; that this being the first appearance of the Society before the Legislature it was very important that the legality of the provisions of the bill should be inquired into in advance by those most competent to judge. Those opposed held, that as several members of the committee that had prepared the bill were United States Deputy Mineral Surveyors whose experience in matters affected by the mineral laws had been long and varied, their opinion as to the legal features of the bill was at least as good as any other that could be obtained and that it would be a needless expenditure to secure the opinion of a lawyer. A vote being taken on the amendment resulted in its being lost.

The motion by Mr. Foss was then put and carried.

The following is a copy of said bill as printed for the House:

§ 1. That Sections 1477, 1478, 1479, 1483, 1484, 1485 and 1486 of the Fifth Division of the Compiled Statutes of Montana be amended so as to read as follows:

REQUIREMENTS OF LOCATION.

§ 1477. Any person or persons who shall hereafter discover any vein or lode bearing gold, silver, cinnabar, lead, tin, copper or other valuable deposits, or who shall hereafter discover or locate any placer deposits of gold, or other deposits of minerals, including building stone, limestone, marble, coal, salines and saline springs, clay, sand or other mineral substances having a commercial value, may

locate a claim upon such vein, lode or deposit by defining the boundaries of the claim in the manner hereinafter described, and by posting a notice of such location at the point of discovery, which notice shall contain:

1. The name of the lode or claim.
2. The name of the locator or locators.
3. The date of location.
4. If a lode claim, the number of lineal feet claimed in length along the course of the vein each way from the point of discovery, with the width on each side of the center of the vein, and the general course of the load or vein as near as may be.
5. If a placer or mill site claim, the number of acres or superficial feet claimed.

Before the expiration of sixty days from the date of posting such notice upon the claim, the locator or locators shall sink a discovery shaft upon the lode or claim (mill site claims excepted) to the depth of at least ten feet from the lowest part of the rim of such shaft at the surface; or deeper if necessary to show a well-defined crevice or valuable deposit.

Any open cut, cross-cut or tunnel which shall cut a lode at the depth of ten feet below the surface, or an adit of at least ten feet in length along the lode from the point where the lode may be in any manner discovered, shall be equivalent to a discovery shaft.

The locator or locators shall define the boundaries of his or their claim by marking a tree or rock in place, or by setting a post or stone at each corner or angle of the claim. When a post is used it shall be at least four inches square by four feet six inches in length, set one foot in the ground, with a mound of earth or stones four feet in diameter by two feet in height around the post, surrounded by a circular trench six inches deep and one foot wide. When a stone is used, it shall be at least six inches by six inches by eighteen inches, set two-thirds of its length in the ground, with a mound of earth or stones alongside, surrounded by a circular trench as above required; which trees, stakes or monuments shall be substantially marked.

RECORD OF LOCATION.

§ 1478. Within three months of the date of posting the location notice upon the claim, the locator or locators shall record his or their claim in the office of the Recorder of the county in which such lode or claim is situated, by a location certificate which shall contain:

1. The name of the lode or claim.
2. The name of the locator or locators.
3. The date of location.
4. If a lode claim, the number of lineal feet claimed in length along the course of the vein, each way from the point of discovery, with the width on each side of the centre of the vein, and the general course of the lode or vein as near as may be.
5. If a placer or mill site claim, the number of acres or superficial feet claimed.
6. The dimensions and location of the discovery shaft, or its equivalent, sunk upon lode and placer claims.
7. The location and description of each corner, with the markings thereon.

The locator, or one of the locators, or the attorney duly authorized of a corporation, shall make oath to the above certificate before some officer duly authorized to administer oaths.

Any location certificate which does not contain all of the information required above shall be void.

RECORDS HERETOFORE MADE ADMITTED IN EVIDENCE.

§ 1479. All records of placer mining locations or locations of valuable mineral deposits, which have heretofore been made in the county records of the county in which the same may be situated shall have the same force and effect as though such records had been authorized by law, except in cases where the rights of third persons had been acquired before the passage of this Act; and such records shall be admitted in evidence before any court in the same manner as the records of location of quartz or lode mining claims; *Provided, further*, that the provisions of this section shall only be construed to impart notice to the public of such claim, but no person shall by reason of this section acquire any or further rights.

PROOF OF ANNUAL LABOR.

§ 1483. The owner or owners of any quartz lode claim who shall perform, or cause to be performed, the annual labor or make the improvements required by the laws of the United States, in order to prevent the forfeiture of the claim, may at any time during the year, or within sixty days after the termination of said year in which said work was done or improvements made, file in the office of the County Clerk and Recorder of the county in which said claim is situated, an affi-

davit or affidavits of the person or persons who performed such labor or made such improvement, showing:

1. The name of the lode and where situated.

2. The number of days work done and the character and value of the improvements placed thereon.

3. The date or dates of performing said labor and making said improvements.

4. At whose instance or request said work was done or improvements made.

5. The actual amount paid for said labor and improvements; and by whom paid when the same was not done by the owner or owners of said quartz claim. The Clerk and Recorder of the county in which said affidavit or affidavits are filed shall record the same in a book kept for that purpose, and be entitled to a fee of one dollar for recording each separate affidavit. When the affidavits are made jointly by two or more persons he shall be entitled to an additional fee of twenty-five cents for each name after the first; and said fee shall be the only one to which the recorder shall be entitled for filing and recording said affidavit and indexing the same.

The affidavit or affidavits named in this section, or copies thereof duly certified by the Recorder of the county, shall be received or admitted in evidence in any court of justice in this territory and be *prima facie* proof of the facts recited therein.

AMENDED LOCATION BY THE OWNER.

§ 1484. If at any time the locator or locators of any mining claim heretofore or hereafter located, or his or their assigns, shall apprehend that his or their original certificate was defective, erroneous, or that the requirements of the law had not been complied with before filing, or shall be desirous of changing his or their surface boundaries or of taking in any part of an overlapping claim which has been abandoned, or in case the original certificate was made prior to the passage of this law, and he or they shall be desirous of securing the benefits of this act, such locator or locators, or his or their assigns, may file an additional certificate subject to the provisions of this act; *Provided*, That such amended location does not interfere with the existing rights of others at the time of such relocation, and that no such amended location or the record thereof shall preclude the claimant or claimants from proving any such title or titles as he or they may have held under previous locations.

RELOCATION OF ABANDONED CLAIM

§ 1485. The relocation of abandoned lode or placer claims shall be by sinking a new discovery shaft and fixing new boundaries in the same manner as if it were an original location made under this act; or the relocator or relocators may sink the original discovery shaft ten feet deeper, in which case the certificate of location shall give the depth and dimension of the original discovery shaft at the date of such relocation. In any case, whether the whole or part of an abandoned claim is taken, the location certificate may state that the whole or any part of the new location is located as abandoned property.

LOCATION SURVEYS.

§ 1486. Where a claimant shall have the boundaries and corners of his claim established by a United States Deputy Mineral Surveyor, and his claim connected with a corner of the public or mineral surveys or an established initial point, and shall incorporate into his location certificate the field notes of such survey, and shall attach to and file with the required location certificate, in the office of the County Recorder of the county in which such claim is situated, a certificate by the surveyor setting forth:

1. That said survey was actually made by him, giving the date thereof.

2. The name of the claim surveyed and the locators thereof.

3. That the description incorporated in said location certificate is sufficient to identify the claim: such certificate and the certificate of the surveyor, or copies thereof duly certified by the County Recorder, shall be received or admitted in evidence in any court of justice in this Territory, and be *prima facie* proof of the facts recited therein.

§ 2. Any claimant of a mining claim located previous to the passage of this act may avail himself of the provisions of this section by making an amended location of said claim in conformity with the requirements of this section.

§ 3. For recording the surveyor's certificate the County Recorder shall receive a fee of one dollar.

§ 4. Any law or parts of laws in conflict herewith are hereby repealed.

Mr. Foss moved that the Committee be continued and that they be instructed to present the bills upon Town Plats and Mineral Locations in proper form to the Legislature of Montana. Carried.

Mr. Keerl moved, that Committee be instructed to secure sixty copies of the Bill on Mineral Locations for this Society and that they be handed the Secretary, and that Secretary be instructed to send each member of the Society a copy, accompanied with a printed slip requesting Members to use all the influence possible with their representatives looking to securing the favorable action of the Legislature upon said bill. Carried.

Mr. Foss moved that a vote of thanks be tendered Mr. George H. Robinson for his able communication to the President of this Society, upon which was based the bill just adopted ; that the Secretary notify Mr. Robinson of the action of this meeting, and that his said communication be placed on file. Carried unanimously.

The Chair and others stated that they had seen several of the legislators relative to the two bills adopted by this Society, and that they had expressed themselves in their favor.

Mr. Ellison moved that it is the sense of this meeting that sufficient notice has been given to Members of the regular meeting occurring the 16th inst. through the ballot list for membership and the pending amendment to the Constitution, relieving the necessity of the Secretary sending out special notices. Carried.

[*Adjourned.*] J. S. KEERL, Secretary.

FEBRUARY 16, 1889:—The regular monthly meeting was held at the office of Mr. Beckler, Mr. W. W. DeLacy in the chair. There were present Messrs. Ellison, Herron, Walker, Kemna, Foss, Wheeler, Lothrop and Keerl.

Minutes of the three sessions of the annual meeting and of the two sessions of the special meeting held the 11th and 12th inst. were read and approved.

The Secretary submitted thirty-four letter ballots received upon the applications for membership of Messrs. F. A. Ross, James MacFarlane and L. O. Danse, who were elected to membership.

Thirty-one ballots upon the pending amendment to Sec. 1, Art. I., of the Constitution to strike the word civil from the name of the Society, were examined by the tellers, Messrs. Wheeler and Kemna, who reported 15 votes aye and 16 nay.

The report of the Committee upon transfer of members from one Society to another being called for, Mr. Kemna, of that Committee, stated the Committee was not prepared to report, and asked for an extension of time, which was given.

The Committee upon permanent quarters and library reported progress and requested that two more members be added to their Committee. The Chair appointed Messrs. Foss and Ellison as additional members to serve upon the Committee.

The Committee on Memorial to the Legislature praying for the establishment of proper renumeration for expert testimony, submitted a verbal report, stating the receipt of correspondence with the American Society of Civil Engineers and the Engineers' Club of St. Louis, relative to the custom in New York and Missouri, being to the effect that the law in these States did not cover the feature of providing suitable remuneration, but that it was customary to arrange with principals the amounts that would be expected. The Committee stated that to proceed further and frame a proper memorial, they should have the assistance of a lawyer, as an extended knowledge of the statutes of Montana would be essential in covering all the legal features involved that the Memorial might stand the test of legal criticism. The report of the Committee was received and laid on the table.

The further consideration of the motor line crossing of Main street, Helena, heretofore discussed, was postponed until such time as Mr. Cumming may lay before a meeting a map and profile of Sixth avenue as far as affected.

Mr. Foss, Chairman of the Committee having in charge the framing of the two

bills adopted at the special meetings of the 11th and 12th inst., presented a bill for clerical services for $6, which was ordered paid.

The Secretary was instructed to secure bids for printing the list of members and to report at the next meeting.

The Chair appointed as the Committee on Topics for the current year Messrs. Ellison, Walker and Hovey.

It being reported that Mr. Farmer was now located in Utah and would, therefore, not be able to act upon the Committee on Highway Bridges, the Chair appointed Mr. Ellison in his place.

A communication from the Engineers' Club, of Kansas City, of January 18, 1889, was read relative to the action of that body upon the question of bridge reform. A bill had been prepared and presented to the Legislature of Missouri, a copy of which they inclosed, and urged upon this Society similar action with our Legislature. The communication was referred to the Committee on Highway Bridges for report at next meeting.

Mr. R. J. Walker read a paper upon the "Manner of Conducting Public Land Surveys in Montana," which proved very interesting, and was discussed at some length. Mr. Walker's paper was referred to a committee of three, appointed by the Chair, to report at the next meeting a memorial to Congress looking to removing the objectionable features now surrounding the manner of conducting public land surveys in Montana. The Chair appointed as such Committee Messrs. Walker and Foss, and, upon the request of the meeting, added himself as chairman of said Committee.

[*Adjourned.*] J. S. KEERL, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. VIII. May, 1889. No. 5.

ANNUAL ADDRESS OF THE PRESIDENT, BOSTON SOCIETY OF CIVIL ENGINEERS.

BY DESMOND FITZGERALD.

[Delivered March 20, 1889.]

FELLOW MEMBERS:—At the formal request of the Government of this Society I appear before you this evening to deliver an annual address.

This is a new departure for the Boston Society of Civil Engineers. When the suggestion was first made I felt disposed to turn a cold shoulder to the proposal, but as the possibilities for good in the future unfolded themselves to my imagination, I resolved to undertake the task in the hope that the future Presidents may build their structures of more complete proportions upon the foundation here laid.

It is profitable for the members of every profession to assemble at stated intervals to listen to words of encouragement or to scan the horizon together and confer as to what progress their common cause is making.

It is already known, perhaps, that I take a somewhat bright view as to the future of the civil engineer in this country. Everything seems to point in that direction. The rapid and solid growth of this Society from a mere handful a few years ago, to the present large membership, is but an index and example of the changes taking place over our broad land. Who of us has not felt the stimulus and advantages of our interesting and growing meetings and our social reunions. I see no reason why in the course of time those two annual gatherings, one for the absorption of mental food in the shape of annual addresses, and that other happy occasion which we have already dedicated to the absorption of another kind of food, may not come to be looked forward to as festivals of our local fraternity.

The stronger this fraternal feeling becomes, the steadier and more rapid will be our growth by the side of our sister professions, which already occupy so high a place in the regard of our fellow men. We sometimes hear law, medicine and theology referred to as the three learned professions, but when we consider the ever forward march of progress in the world, the increasing calls for the highest talents the

brightest minds and the most unremitting study, in the production of those material works which an advancing civilization demands for the welfare of the race, it requires no prophetic eye to see that the civil engineer will soon enter the list of professions which compete for the upholding of the social compact.

I have alluded to the changes rapidly taking place in the civilized world. Is not the false standard by which the past has measured its heroes giving place to a better judgment? Do the military conquests of a Cæsar, an Alexander or a Napoleon challenge the admiration of mankind as they once did?

Is there not already a better appreciation of the noiseless though mighty work of a Newton, a Stephenson, a Bell, an Edison, a Francis or an Eads? I think we may depend upon it that in the wonderful strides which science is making all over the world the profession of the civil engineer will not suffer. I am well aware that for the engineer to be properly paid for his services will require a radical change in many directions, but perhaps these movements may be hastened by the free circulation of ideas and the educating and broadening influence of just such organizations as our own. Within the sound of my voice, and certainly within the boundaries of this Society, are men who are giving their life's best services to the advancement of the interests of large corporations for the veriest pittance. Particularly is this true of railways, and in a more marked degree in New England than in other portions of the country. I can speak on this subject both from investigation and from personal experience, and I know that it is perfectly possible to find men whose labor is so unremitting from early morn until late at night, and even during the whole seven days of the week, that they have hardly time to call their souls their own, whose resources and responsibilities are taxed to the utmost for a compensation so meagre that a respectable existence is almost the only reward. The expenditure of hundreds of thousands of dollars, and even millions, is often controlled and designed by men whose salaries hardly exceed the pay of a good foreman.

On such an occasion as this, however, the mind should not be allowed to dwell long on the discouraging side of any question; let us turn, therefore, to other and brighter scenes.

In casting about for a subject for this address I found no precedent to guide me, for, as far as I have been able to learn, this is the first address of a president of a society which has an honorable organization extending back to the year 1846.

Instead of roaming over the broad and attractive fields of the profession, I thought, perhaps, it would be more instructive, and at any rate as appropriate, to take one or two subjects near at hand; and, in fact, drawing a line around our own commonwealth there is quite enough within her boundaries to occupy our attention for a number of evenings.

To be sure, we have few mighty rivers to span. No grand suspension bridges, no long steel arches, no jetties like those at the mouth of the Mississippi, no mighty dams, and no lines of railway like those which link together the vast regions of the West, adorn our borders. Still Massachusetts is making satisfactory progress. Her population has

grown in the ten years—1875–85—17.5 per cent. Her products have increased steadily from $158,000,000 in 1850 to $631,000,000 in 1880. Even agriculture, which is supposed generally to be on the wane, shows an encouraging advance. The increase of farming produce in ten years, according to the last state census, was shown to be 28.8 per cent. There are some achievements of engineering skill in our State to which we may refer with pardonable pride. Of many of them I cannot speak to-night, and of others only in the most cursory way. I suppose in the development of our municipal engineering we are hardly behind our sister States. Our water-works and sewage system have been much praised outside of our own borders and even by foreigners who have visited our shores. These have already been sufficiently described and illustrated. Your time would be wasted were I to dwell on them.

In the development of water-power used for manufacturing purposes Massachusetts stands second in rank among the States of the Union. New York takes the lead and Pennsylvania stands third, but if we take these three great hydraulic centres, Holyoke, Lowell and Lawrence, where the power of 35,000 horses is daily utilized from the flow of the Connecticut and Merrimac Rivers, we shall hardly find their equal, as far as the scientific development of power is concerned, in any portion of the globe. It is to these three places to which I wish to take you in imagination this evening. In order that the principal points of interest may be fully illustrated, I have had some fifty views taken and lantern slides made so that we can follow the description with the stereopticon.

LAWRENCE.

If Lawrence is smaller, as a water-power centre, than either of the places mentioned, we shall find the works simply and systematically designed, the mills compactly built in continuous lines along the river, and that certain hydraulic problems have been studied, which have not been considered elsewhere.

The water-power was developed by the building of the dam 1845–8. Mr. Charles S. Storrow, one of the most accomplished engineers of his time in Massachussetts, designed and built the Lawrence Works.

I am happy to say that Mr. Storrow is still with us to-day, hale and hearty, and that he takes an active interest in the advances of his profession.

The dam, which has a length of about 900 feet, is slightly curved in plan. It is solidly built of masonry and founded on a hard slate rock which has shown very little scour under the action of the water-fall. Its maximum height is about 40 feet and it is 35 feet wide at the base.

From the dam there are two canals which convey the water to the mills, one on each side of the river. As the south canal is quite short and comparatively unimportant in its present stage of development, the north canal is the only one which need engage our attention this evening. This canal is a mile in length and follows parallel to the river, discharging at its terminus into the Spicket River, at its confluence with the Merrimac.

Between this canal and the river are thickly clustered the celebrated mills which have given Lawrence a world-wide fame. They take their

water from the canal on the one side and discharge directly into the river on the other.

Here we will find the great Pacific Mills, with their 23 buildings, 160,000 spindles and 5,300 employés; the Atlantic Cotton Mills, with 101,000 spindles and 1,200 employés, and the Washington Mills, with 2,660 employés. The other principal mills are the Pemberton, Arlington, Everett and the Lawrence Duck Company, with a host of minor corporations.

The gate-house at the head of the north canal contains six sets of gates. Each gate is in four leaves, which are raised one at a time as the screw is turned, until all four are up. This work is done by hand-power. This kind of gate is no longer in use at either Lowell or Holyoke.

Each leaf is 3 feet high by 9 feet wide. A lock at the side of the gate-house allows the entrance of boats to the canal and another set of three locks at the other extremity of the canal gives an outlet to the river.

The north canal is not rectangular in section. It is 100 feet wide at the upper end, 60 feet at the lower end and has a depth of 12 feet in the centre. On the sides are two shallow walls, then a berme of 8 feet and then slopes of two to one to the bottom. It will be noticed that the section is not a favorable one for measuring the flow of water. The fall of the water is about six inches in the one mile of canal. The head from the canal to the river averages uniformly about 28 feet for its whole length, and this is the measure of the power at Lawrence.

The number of water-wheels is 59, of which 20 are Boyden, 14 Swain, 9 Hunt, 5 Risdon, 3 Hercules, 3 Victor, 3 Leffel and 2 National. This is perhaps a favorable place to say a word in regard to water-wheels. The old Boyden, at speed gate wide open, or running at full gate as it is called, has never beeen surpassed in duty by other wheels, but it is a poor wheel for economy when the speed gate is partly closed. There are several wheels now manufactured which are very much cheaper and which are better than the Boyden at partial gate. It is questionable, however, if any of them will prove as durable, for there are Boyden wheels now in use which have been running for many years with very slight repairs. Notwithstanding this fact, it is extremely doubtful whether many more Boyden wheels will ever be built. The advantages of procuring a more economical wheel in duty, for less than one-half the price, and ready made, like a pair of shoes, to put into instant service, are too apparent. Again, the exigencies of manufacturing often require an increase of power and several of the modern types of wheel can be taken out and another inserted with the greatest facility.

There is now a movement toward horizontal wheels. These can, of course, be attached directly to the shaft which runs a mill without the intervention of heavy gearing and the consequent loss of power. Another advantage in the horizontal system comes from the avoiding of the wearing of the step. On the other hand, there are special difficulties in the horizontal system which have to be overcome. The draft tube which carries the water to the tail race must be perfectly tight to secure the benefit of the fall, for the slightest amount of air would impede the useful effect of the water. There are eight horizontal wheels in use at Lawrence. The one which you now see on the screen is in the

Wright Manufacturing Company's mill. There is a large field for a good set of experiments on this type of water motor; in fact, the farther one goes in the study of hydraulics the better satisfied he becomes that the science is by no means exhausted.

In the Atlantic Mills may be seen the four original Boyden wheels substantially as they were set by Boyden himself. They are still in use. In the Washington Mills are 40-inch horizontal wheels. In the Everett Mills can be seen an old 93-inch Boyden, and by its side a 54-inch Hercules, both fed by an iron penstock 8 feet in diameter.

The finest wheel-room that I have found anywhere is in the Pacific Mill. Here three Swain wheels are systematically geared to a large shaft. The belt well, where the power is transferred to the different floors, is worth visiting. The longest belt measures 250 feet.

Nowhere else has the problem of the accurate measurement of the flow of water supplied to the different mills received more thoughtful study than at Lawrence. Mr. Hiram F. Mills, the engineer of the Essex Company, has already made an enviable reputation for ability and care in this particular branch of hydraulic work.

Although few of the Lawrence experiments have ever been published, it is expected that when the Lawrence hydraulic experiments are given to the world they will prove as interesting as the Lowell book, which is known wherever the science is studied.

The canal at Lawrence, as I have already stated, is poorly adapted to accurate measurements of flow. Aside from this fact there is an objection to estimating in this way the surplus water to be paid for by the mills. Each corporation under its deed has the right to a certain permanent power which forms perhaps at any given time of measurement the great bulk of the flow. The surplus or the small percentage over and above this fixed amount is the quantity which it is necessary to measure with the greatest possible refinement of method, and yet owing to the difficulties in measuring precisely large quantities of water the error of measurement may be the very sum which the mill may be called upon to pay. To get at the quantity supplied to any mill, from measurements made in the canal, two measurements are necessary, one above the intake to the mill, and the other below this point, the difference between the two giving the supply to the mill. Should, however, the errors both be in the same direction, the surplus of the mill might be largely affected. At Lawrence the measurements are preferably made in the penstocks by one measurement which gives the quantity flowing to each wheel as a check on the flow computed from the head and fall at each wheel. The measurements in the penstocks cannot be done by the ordinary methods pursued by engineers, and has led to the use of the Pitot tube, which has been so modified and perfected that all the heads due to velocities in different portions of a section are brought up to one key-board, where they can be conveniently read.

I regret that I cannot give you farther details with views of this interesting work. This portion of the hydraulic problem is *the* feature of the Lawrence methods, and its development will be watched by all engineers with interest.

A pleasing feature connected with the construction of the Lawrence

mills is the location of the tenement houses for the employés. They are situated on the opposite side of the canal to the mills, are built of brick and surrounded with shade trees, making an interesting out of what is too apt to be an ugly part of the landscape in a manufacturing centre.

A mill power at Lawrence is the right to draw 30 cubic feet per second for 16 hours on a fall of 25 feet.

LOWELL.

The history connected with the development of the water supply of Lowell is an extremely interesting subject, but one to which we can hardly do justice this evening.

It will be sufficient to recall to your memories that the Pawtucket Canal, one of the principal feeders of the Lowell system, was opened in 1796 for navigation around the Pawtucket Falls. It is about 1½ miles across the bend to the Concord River just above its confluence with the Merrimac. One of the strong incentives for building the canal was the fact that logs from New Hampshire had to be hauled across this bend to escape the falls. In 1822 those far-sighted and energetic men, Lowell, Appleton, Jackson and Boot, obtained control of the water-power, and proceeded to develop it for manufacturing purposes. The first wheel was started in the Merrimac Mill in 1825. Lowell to-day is a prosperous city of about 75,000 people, and it is safe to say that she owes a large share of the good character of her inhabitants and her institutions, to the names I have mentioned, who, along with the mills which they erected, built the church, the school-house and the library.

As we examine the ground plan of the present works we notice a complexity of lines which seem to lack simplicity in design. The canals have, in fact, been built at various periods, as exigencies have arisen, and they seem to run around in every possible direction. Even the dam itself, a structure which we are accustomed to look upon as either straight or curved in plan, seems overcome with the general disorder, and wanders about at all conceivable angles, in some places parallel with the current. Notwithstanding this, there has been a most intelligent supervising power in it all, and as we study into the details we find there has been good ground for every step of growth. However, any one who desires to carry the whole of the Lowell plan in his head will have to return to the study of the subject again and again. It will be noticed that, unlike Lawrence, the Lowell works are all situated on one side of the river only.

The present dam is of masonry, and of the section shown on the screen. The portion built in 1887, was laid of dry ashlar, and as some of the stretchers afterwards moved out of place the new dam was laid dry and grouted course by course with pure Portland cement. By this method of construction, even if the cement should fail, there could be no settlement in the mass. The length is 1,093.5 feet and the height varies from 2 to 16 feet, excepting in one deep hole, where the foundation was 33 feet below the crest.

The dam backs the water in the river a distance of 18 miles, or about twice as far as does the Lawrence dam, and thus provides an immense

reservoir for the storage of the flow of the river during the night, at which time no water is used in the mills. The present dam was built in 1875–6 by Mr. James B. Francis, Member of this Society, whose fame as a hydraulic engineer extends into every land where the science of hydraulics has a foothold. Mr. Francis has designed nearly all of the Lowell works.

The great North canal will long remain a monument to his skill. I have already called your attention to the course of the canals around and through the city. The Pawtucket Canal was the old one, as you will remember, running across the bend of the Merrimac and uniting with the Concord River. The Northern canal, which is a beautiful piece of engineering construction, follows closely the bank of the main river for a portion of its length. In the view now on the screen you will notice the great wall which separates the canal from the river.

The head gates to both canals are operated by water-power, but differently applied. The Northern canal is fed through ten gates, each 8 feet by 15 feet. They are operated from a line of shafting driven by a turbine wheel.

In the gate house at the head of the Pawtucket Canal there are five gates each 9 feet by 10 feet. The spindles of these gates are connected with a piston in a cylinder, and the gates are raised and lowered by pressure from a water main.

Over one of the locks in the Pawtucket Canal is a high building, in which hangs an enormous wooden gate suspended from a truss by an iron link. To lower the gate, the huge link must be cut through with cold chisels. The history of this great gate is interesting. Mr. Francis, fearing that a freshet might some day arrive which would overflow the canal and flood the city, constructed this gate in such a manner that the link could be chipped through, the gate dropped and the city saved. It is said that there were many men who wagged their heads knowingly at this seemingly unneccessary precaution. Some even went so far as to call it "Francis' Folly." Strange to say, only a short time after its completion, the disastrous freshet came, the giant gate was cut loose and the city protected from inundation. It would be invidious to say that some men are born lucky, but I have heard the remark made by aspiring engineers when looking at this gate.

The Northern canal is 100 feet wide and about 18 feet deep. It cost $500,000 and carries twice as much water as the Pawtucket Canal. The river wall is 36 feet in height, and of the section shown on the screen. It is provided with waste gates and overflow, a short distance below the dam. There are six smaller canals forming a net-work in the city and distributing the water brought by the two great feeders to the mills, in all about five miles of canal. They are of rectangular section and about 10 feet in depth. The Moody street feeder is a covered structure of three arches, each of 10 feet span. Its length is about one-quarter of a mile and it was built to connect the Merrimac and Western canals. Its cost was $86,000.

The total fall at Lowell is 33 feet, mostly distributed in two levels of 14 feet and 19 feet respectively. About one-sixth of the water is used on the whole fall and the remainder on the two levels just mentioned.

A mill power is defined as the right to draw 25 cubic feet per second on a 30 feet fall for 15 hours. The power is all owned by the proprietors of the locks and canals on Merrimac River. a corporation which in turn is owned and controlled by the mills using the power under perpetual leases. The price of water-power is consequently very low, something like $3.53 per horse-power per annum. There are 77 turbine wheels in use, of which 50 are Boyden, 26 Swain and 1 Humphrey. One of the Boyden wheels is 132 inches in diameter.

The method of measuring the water supplied to the mills varies somewhat from that in use at Lawrence or Holyoke. We cannot go into very full details. but it will be readily understood that circumstances and construction have everything to do with methods of measuring the flow, and that what answers well in one place will not always be applicable in another. There are no piezometric observations as at Lawrence, but careful flume measurements made in the canals take their place. I have had a slide made of one of these measurements in course of operation. A section of canal is carefully prepared for this purpose, and the velocities are taken by means of long tin tubes. weighted, and which are floated between known points and their direction and time taken. At Lowell there is no room to measure the water running in the tail races, as the mills are built directly over the river.

The velocity in the canals is very considerable. I have often noticed the water running as fast as 3.5 per second. It is always interesting for a hydraulic engineer to form some rough idea of the quantity of water flowing in any water supply system, although in the absence of uniform standards for estimating large quantities of water it is not always possible to convey to others a definite idea by the same unit. On one visit I found the canals carrying over 5,000 cubic feet per second, which would practically empty Lake Cochituate in one day. At this same time they were using rather more than this at Holyoke, 7,000 cubic feet per second, counting the day and night run, 4,000 cubic feet per second during the day and 3,000 during the night. One of the perfections of the Lowell system is that the water-power is all utilized practically without waste.

The Merrimac River, which turns the wheels of Lawrence, Lowell and other large manufacturing towns, is said to be the most noted water, power river in the world, for nearly its whole course of 100 miles from its sources to the sea its power is utilized. It has been estimated that there are 100 miles of reservoir surface at its upper waters which afford unsurpassed reservoirs for equalizing the supply. These make the river remarkably steady in flow. Again, the fall of the stream, while only averaging 2½ feet to the mile, is concentrated at a few points and at rocky falls, which enables the power to be easily developed. This same cause contributes to prevent those sudden and extraordinary freshets which visit Southern and Western rivers.

The area of the water-shed above the dam is about 4,000 square miles. Any one desiring to go farther into the details connected with the Lawrence and Lowell powers will find able and interesting articles in the 10th census from the pen of Professor Swain and one on Holyoke by Professor Porter.

Lowell has been called the incarnation of a hive of industry. There are about fourteen and a half millions of dollars invested in its ten largest corporations. These are the Merrimac, Hamilton, Appleton, Lowell, Middlesex, Tremont and Suffolk, Lawrence, Boot and Massachusetts Mills, and the Lowell machine shop and the Lowell bleachery. The number of spindles is 846,000, employés 18,000, and nearly five millions of yards of cotton cloth are woven weekly. Besides these ten large companies there are numerous smaller corporations, engaged in the manufacture of all kinds of articles. In addition to the water power employed, seven of the above mills have 140 steam engines of 18,150 total horse power and they use 57,844 tons of coal yearly, while their weekly pay roll amounts to $81,038. In the Lowell machine shop a mill of 40,000 spindles can be fully supplied with machinery in three months' time.

I do not intend to weary you to-night, however, with long columns of statistics, however strong the temptation may be, and so will pass at once from the Merrimac to the Connecticut River.

HOLYOKE.

Holyoke boasts the largest water-power of any of the great manufacturing centres of Massachusetts. Here the whole of the Connecticut River, with its 8,144 square miles of water shed, is captured and turned into mill powers. The capital used is about $15 000,000, and 12,000 hands are required to run the various mills. The water-power developed during the day is about 15,000 horse-power, and in the night about 8,000. The visitor cannot but be impressed with the excellent design of the works, built in 1849. I refer particularly to the systematic and comprehensive plan. The canals were so placed that very little alteration has been necessary as the power has been developed.

If we had time to glance at the historic side of the Holyoke works we should profit from many interesting engineering lessons, such as the carrying away of the first dam and the many defects in the present one.

Fortunately this matter has already been ably presented to the society by Mr. Clemens Herschel, the engineer of the Holyoke Water-Power Company, in a paper describing the dam, the dangers from decay and the steps taken for its preservation.

For the benefit of those who did not hear the paper I will simply state that the cob work of which the dam is constructed was filled with a grouting of gravel ingeniously applied, The height of this structure is 35 feet; length, 1,017 feet, and 13 feet of water have passed over its crest.

The bottom course of timbers was bolted to the ledge on which it rests. The apron which you have seen in the views was an afterthought, and only added when it was found that the force of the water was wearing a great hole in the rock. This apron is 50 feet wide at the base and its cost was $263,000.

In connection with the dam there are the abutments, the bulkhead for the canal, the lock walls, waste weirs and gate house.

The bulkhead to the canal is 40 feet wide and is pierced for twelve large gates, each 8 feet by 15 feet, and two smaller openings. These are covered by a brick building which forms the head gate house. The openings are controlled by massive wooden gates, which are operated by a

shaft and gearing worked by a turbine at the dam end of the gate house.

The waste weir in the canal just below the gate house is an important piece of masonry, pierced at its lowest level for gates to empty the canal, and surmounted by a long overflow and flash boards in the usual manner. The total fall at Holyoke is 60 feet, to which the dam contributes 35 feet, and the rapids below the dam 25 feet more, a splendid power when we consider the large volume of water flowing in the Connecticut. There are three levels in the canals. The first has a fall of 20 feet to the second, and the second 12.5 feet to the third, from which the water escapes again to the river with a fall of 27 feet. The first canal is rectangular in section. It is 150 feet wide at the upper end and there is a gradual reduction in width throughout the system to 100 feet in the third canal. The general depth of the water is from 8 to 10 feet.

The canals have been well designed for control by a small force. A single man stationed at the junction of the first and second level does the principal work. This point is but a few steps below the gate house so that the same man can work those gates also. The overflow from the second canal into the river is within convenient reach of the same gate keeper. This view shows the second level, the gate house which controls the waste to the river, the overflow from the upper level 40 feet in length, and the lock. There are also gates in the bulkhead. By means of these arrangements water can be fed to the second canal independently of the discharge from the mills on the higher level.

The first canal is more than a mile in length. The second is parallel and but a short distance from the first, but the third canal is at a considerable distance from the others, with a large part of the city between. The course of the third canal is parallel with the river. A waste weir 80 feet in length at the end of the second canal discharges surplus water into the third and there is still another leading from the third canal into the river.

There are some points in which Holyoke differs materially from Lowell and Lawrence. There is comparatively little steam used, as the river with its large fall is sufficient to do nearly all the work required. A large number of the mills are paper mills running night and day from Sunday night to Saturday night, six days out of the seven. Under these conditions of manufacturing, the large flow of the stream is an important factor in the development of the power. At Lowell, for instance, there is the run of ten hours and the rest of fourteen, during which the large mill pond above the dam can fill up. At Holyoke a mill pond of greater capacity than that necessary to store one day's flow is useless.

The paper industry at Holyoke is the largest in the United States. Acçording to the tenth census, there were, in 1882, twenty-three companies engaged in this branch of manufactures, employing 4,000 hands and turning out a finished production of from 150 to 160 tons per day. The quality and variety of the paper is astonishing. The fine grades of writing paper are said to rival any in the world. Besides the paper mills there are many other extensive manufacturing establishments, but the mills strike the visitor as older and not as fine as those at Lowell and Lawrence.

The method of measuring the water at Holyoke is somewhat different

from that pursued at the other places already described. The measurements are based entirely on the observations on the water wheels which are made to act as their own motors without other check. Before the wheels are set, they are put into the testing flume and their duty carefully measured for several openings of speed gate and under different heads. From these tests curves are plotted for the various conditions of service. This testing of water-wheels is a specialty at Holyoke and no where else in the world are there the same facilities for doing this work.

A flume designed for the purpose by Mr. Herschel has been built by the Holyoke Water Power Company at an expense of about $30,000.

When it is desired to test a wheel at any other place than Holyoke a special arrangement of apparatus must be improvised and such a test may easily cost $2,500.

The Holyoke Water Power Company are ready to do this same work at any time for $100 to $150, consequently wheels from all parts of the country are sent to them to be tested.

The flume consists essentially of a large masonry chamber to which the water is brought by an iron trunk from one of the canals. The flume is built so as to facilitate the easy setting up of a wheel, the application of the Prony brakes and the measurement of the water over a 20 foot weir having a capacity of 200 cubic feet per second. Over the whole is a substantial building containing repair shops and offices. Wheels are usually tested for five or six openings of the speed gate and at five or six different velocities of revolution at each opening, or about thirty experiments in all. The wheels to be tested are swung into the building by a traveling windlass and lowered into the wheel pit. The power is weighed by a Prony brake consisting of a cast-iron pulley surrounded by a hollow brass band through which a stream of water is allowed to circulate. A bent lever and weights hold the band and pulley in place. There are five sizes of pulleys and bands. To enable the observer at the brake wheel, the one at the head gauge and the one at the weir to take simultaneous observations at intervals of one minute, an electric clock is rigged to ring three bells at the same instant. The masonry of the testing flume is so perfectly laid that under 20 feet head it is scarcely damp on the inside.

Of the 134 wheels at Holyoke 74 are Hercules, 33 Boyden, 9 American, 8 Tyler, etc. The Hercules, which is so largely used at Holyoke and elsewhere, is a high duty wheel, economical, ready made and can be easily set and taken out. By means of its ample water-power, Holyoke has grown from a mere village to a city of 30,000 inhabitants. The Water-Power Company, whose franchise was purchased of a bankrupt corporation in 1859 for a small sum, is now a wealthy corporation whose stock sells at about 250 and whose dividends are about 15 per cent. In addition to disposing of water to the mills, the company has built several mills which are leased for water-power purposes. A mill power at Holyoke is the right to draw 38 cubic feet per second on 20 feet fall for 16 hours, or 86.3 theoretical horse-power. If a turbine gives 80 p. c. duty, a mill power would yield 69 horse-power.

COAST WORKS.

An examination of the coast of Massachusetts will show that the gen-

eral government has expended a large amount of money in works of an engineering character, principally in the improvement of the harbors.

As engineers we should be thoroughly informed in regard to the purpose of these works and their failure, if any, to meet the expectation of those who designed them. I shall not attempt to go into the details of the minor work, such as dredging, the removal of sunken rocks and ledges, and the erection of lighthouses; still I think it will be profitable for us to-night to take a little trip in imagination along the shore, stopping at points of special interest, *en route*, and attempt the pleasant task of fixing in our minds their particular characteristics.

Starting from the north, the mouth of the Merrimac River is the first part of the coast on which the Government has expended any money. Here, a short distance up the river, is the interesting old town of Newburyport. A sand bar, formed by the sea, limited navigation to a depth of from six to seven feet. Two stone jetties have been partially built, tending to confine the current of the river to a narrow channel. These jetties are built with a slope of two to one on the outside, and one to one on the inside, and they are both together something more than a mile in length. They will be fifteen feet wide at the crest, which is twelve feet above mean low water. The bar has already been deepened about five feet, and about five feet more remains to be scoured out to complete the plan, giving seventeen of water in all.

About $170,000 has been expended in dredging the river as far as Lawrence. Including the jetties, $375,000 has been spent by the United States in this neighborhood. One of the common effects of jetty building is to concentrate the currents or to change their direction to such an extent as to deepen the ground parallel with the lines of the jetties, causing them to settle.

Sometimes the discouraged engineer finds an enormous hole at the end of the uncompleted work, which has to be filled with quarry grout, and this goes a long way toward eating up the 10 per cent. for contingencies usually allowed in engineering estimates.

A short distance south of the Merrimac we come to Cape Ann, and here we find a project under way for building a harbor of refuge, which, if carried out, will be the largest artificial harbor in the world, not excepting the far-famed harbor of Cherbourg. The Sandy Bay breakwater is building in water from 7 to 90 feet in depth. It is composed of rubble stone 40 feet wide at a point 22 feet below mean low water. On this foundation it is probable that a heavy sea wall will be built, but the plans for the superstructure have not yet been adopted. The anchorage capacity of this magnificent harbor of refuge has been estimated by Major Raymond at 5,000 vessels of all classes. The cost has been estimated at $5,000,000 without buoys, forts or lights, and these will cost half as much more.

At the present rate of progress, as limited by the yearly appropriations of Congress, there is a remote possibility of our great-grandchildren living to see the work completed.

The only particular point of engineering interest in connection with the construction of the great breakwater is the self-dumping scows, owned by Messrs. Rogers & Scripture, the contractors. They are built for

use in heavy weather. On each side of a central division are two longitudinal water-tight compartments. The stone is placed in the central space, and on being towed to the site the bottom trips out and lets the stone down.

While on the subject of scows, I will show on the screen another kind of self-dumping scow which was successfully used by the inventor, Mr. Edwards, in the construction of the Newburyport breakwater. This scow is adapted to shallow water work and where there is no exposure to heavy seas. The stone is placed on the deck, which is rigged on rollers on a slight incline. On reaching the dumping ground, the deck is allowed to roll a few feet to one side, which causes the scow to tip and thus shoots the stone out, after which the deck returns to its place again. The idea is an ingenious one, and may not be familiar to many present.

At Gloucester $10,000 has been spent in the removal of rocks, and the engineer corps have planned a system of jetties, for which they have asked from Congress three quarters of a million of dollars. We must not pass by the Thacher Island lights without some recognition of their beauty and importance. The twin granite towers are carried to a height of 165 feet above the sea, and they support two fixed white lights of the first order, which are the joy and pride of every mariner who navigates the coast.

At Salem and Lynn harbors a considerable amount of dredging has been done. At the latter $60,000 has been expended, affording a ten-feet low-water channel to the harbor commissioners' line.

We now arrive at Boston, the second commercial port on the Atlantic seaboard, and one of the best and most beautiful harbors in the world. Among the different works executed by the general government in Boston harbor, there are two only of sufficient importance to challenge our attention. These are the sea walls built around the islands for their protection and the extended dredging operations in the upper and lower middle channel, between Castle and Governor's islands. We shall overlook, for the time being, the forts, navy yard and Minot's ledge lighthouse. It will be sufficient to remark that beautiful as the masonry walls of Forts Warren and Independence may be, they are absolutely worthless as works of defense. Fort Winthrop, an earthwork, is of some value, but too thin for modern ordnance, which requires a minimum thickness of eighty feet. At the Minot's ledge lighthouse, the bottom course was laid by Gen. Alexander in cement protected by linen. He thus had the honor of being the first to introduce this method of keeping the mortar intact until it had set, to the engineers of this country. The focal plain of Minot's ledge light is 92 feet above the sea. It is a second order light.

The sea walls around the islands may be divided into two classes, those laid in cement and those laid dry. The former class include

The Lovells Island,
Long Island,
Gallops Island,
Great Brewster and
Point Allerton walls;

and the latter class

The Rainsford,

Georges Island and

The three Deer Island walls.

All of these walls which have been laid dry have had to be backed with concrete, patched in various ways and protected. In a general way it may be said to be a costly error to lay a sea-wall without mortar.

After the islands were denuded of their trees the sea began to make inroads into their sides. Observations made at the Great Brewster showed that from 1820 to 1868 an average of five feet horizontally was washed away yearly into the channel from the big bluff on the north head. The wall which extends three-quarters of the way around this island is a fine specimen of sea-wall of coursed granite 18 feet high on a concrete foundation and backed with concrete. Its bottom is at low water. It has stood perfectly since 1850, when it was begun. The Lovells Island wall is of a similar character. The bottom of the Pt. Allerton wall was placed at half tide, and it has proved insecure. Heavy rip-rap has been placed along its front. The Gallops Island and Long Island walls are in a similar predicament. The bottom of the concrete in the Long Island wall is at grade 6.6 feet.

Through the courtesy of the United States Engineer in charge of the Boston harbor, I am enabled to show you a section of the great Brewster wall which cost $160 a running foot, and also a section of this class of wall as built by the government.

The great improvements which have resulted in the channels of the harbor will be appreciated when I state that the upper and lower middle channel was formerly 18 feet deep and 100 feet wide, and that now it is 28 feet deep and at least 600 feet wide; the depth being taken of course from mean low water. Although four or five millions of dollars have been spent in the improvements in the harbor much more remains to be done. Both walls and dredging must be extended to render the harbor perfect

With the exception of $50,000 spent in a breakwater and dredging in the harbor of Scituate, there is no government work of importance south of Boston until we arrive at the historic town of Plymouth. The struggle since 1825 has been to preserve the Plymouth beach, a narrow sand spit some three miles in length. The sum of $125,000 has been spent in revetments to keep the sea from making breaches through the spit.

At Provincetown, on the extremity of Cape Cod, the problem has been of a similar nature. The harbor at this point is one of the finest, and from its position so far out to sea one of the most important on our dangerous coast. I presume but a few of the members of this Society have ever visited this spot; this view, however, will give an excellent idea of the situation. The principal government work consists of a dike at High Head, in East Harbor. The State has expended $100,000 in closing the inlet to this same pond.

The harbor of Provincetown is to-day in a better condition than it was in 1850. It is here among other points on the coast that Professors Mitchell and Whiting have made such careful studies of the action of the tides. The United States Government works south of the Cape are under another division of administration with headquarters at Newport, R. I.

At Hyannis harbor a small breakwater of granite rip-rap, 1,170 feet in length, was built many years ago. Its section proved rather light, the outer slopes being only one to one. It has been gradually extended during recent years until the outer slope has become two to one. The anchorage back of the breakwater is to be deepened to fifteen and one-half feet.

Before the breakwater was constructed the open roadstead of Hyannis was freely exposed to the southerly winds. Its situation is about 15 miles westerly of the head of the Cape. It is the terminus of one of the branches of the Old Colony Railway. The navigation is intricate and dangerous on account of shoals. A contract for dredging at Hyannis was recently let to the Frank Pidgeon Dredging Company, of New York, for the sum of 14.9 per cubic yard. The next work is a harbor of refuge at Nantucket which takes its importance principally from the fact that, disregarding the small refuge at Hyannis, it is the only one between Provincetown and Edgartown, a distance of about 100 miles. Nantucket harbor has deep water inside, and the object of the improvement is to make it a harbor of refuge for vessels plying between points north and south of Cape Cod, estimated at 50.000 annually. More than 500 vessels have been wrecked in the vicinity of this island. The plan which has been adopted is to build rip-rap jetties, projecting from the sides of the harbor to concentrate the tidal current. More than $100,000 has already been expended, but as the works are still uncompleted it is impossible to state their exact measure of success. The construction of these jetties involves some interesting studies for the hydraulic engineer. Knowing the contents of the tidal prism it is easy to figure velocities with different sections, and so gauge the tidal power to scour the material ; but there are several other questions coming in to complicate the problem, such as the openness of the jetties themselves, their liability to leak under small heads, etc., which all lend an interest to the plan. To any one who desires to pursue the subject further, I recommend the perusal of the report of the Board of Engineers on the Nantucket jetties, made to the Chief of Engineers on July 17, 1885, and the very interesting report of Lieut.-Col. Elliot preceding the same. (Annual Rep. Ch. of Engs., Part I., pp. 561-579.)

At Woods Holl there are two harbors known as Great Harbor and Little Harbor. The works now nearly completed consist in the construction of retaining walls, or hollow pier and wharves for the use of the U. S. Fish Commission, the Revenue, Marine, etc., and the removal of dangerous rocks. About $100,000 has been expended.

Wareham harbor, and estuary at the head of Buzzard's Bay, has had $75,000 spent upon its improvement. Taunton River, emptying into Mt. Hope Bay, has had $50,000 expended upon its channel, and the work is not wholly completed.

THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

Any reference to engineering development in Massachusetts would be incomplete without a hearty acknowledgment of the magnificent work which is accomplished at the Institute of Technology.

I have recently been examining somewhat carefully the past history

and the present condition of this wonderful school, and I cannot repress my admiration for the executive skill and patient industry which have brought the course of study to such a state of perfection.

The Institute includes in its organization a "Society of Arts," a "School of Industrial Sciences," "The Lowell School of Practical Design," and a "School of Mechanic Arts."

There are nine regular courses, viz.: civil engineering, mechanical engineering, mining engineering, electrical engineering, architecture, chemistry, physics, natural history and a course of general studies.

These courses are admirably designed to give a sound, practical, as well as theoretical training. The instruction in mathematics, surveying, drawing and the construction of public works, is particularly excellent, and I only single them out from the others because I am more familiar with them. Some idea may be formed of the advantages which the new building, so-called, affords, when we find that the Kidder Laboratories give accommodations to five hundred students. In February, 1865, the Institute began its work with twenty-seven pupils. To-day it has eight hundred and the number is constantly increasing. In 1865, ten teachers formed the corps of instructors. To-day eighty professors and assistants are required to carry on the school. There is no halting in this good work. The aim is to keep constantly abreast with the times. That engineering has already been honored by graduates of the Institute is an accepted fact. That the advance of our profession will show in the future, even more than in the past, the effects of this admirable training, goes without saying. I fully believe that a considerable share of the improvement of the status of engineers, for which we are all looking will be due to the solid foundation which the Institute is laying. It may interest the friends of this school to know that notwithstanding recent large additions, a new building will soon be begun to meet the growing demands and popularity of the Institute. It may be also gratifying to know that the application for graduating members to fill lucrative places is sometimes larger than the number that can be supplied. I regret very much that time will not permit me to go over some ground which I had laid out in connection with this address. The quarries of Quincy, Rockport and Concord, the new system of parks for Boston, the advances in bridge building, would all form interesting topics for many evenings.

I cannot forbear saying a word in regard to the excellent work which the Railroad Commissioners and the State Board of Health have entered upon. The Society was instrumental, as you will remember, in producing the change of public opinion which finally brought about the passage of an act of the Legislature, soon after the lamentable Bussey Bridge accident, requiring the railways to transmit plans and strain sheets of their bridges to the Commissioners for expert examination. It is to be hoped that out of the chaos which formerly existed in this important branch of transportation, a system of bridge construction and of inspection will be produced which will insure to the traveler a reasonable confidence in passing over the bridges within the boundaries of this State.

The improvements made upon the Boston & Albany Railroad within

the past few years, in the direction of building attractive stone stations, and the laying out of their grounds in a tasteful manner, under the care of a competent landscape gardener, are to be commended. This work has done much toward raising the somewhat low standard which formerly existed. It was only fifteen years before the organization of this Society that the specifications for an engine read as follows:

"The engine when in operation must not exceed 3½ tons weight, and must on a level road be capable of drawing day by day 15 tons, including the weight of wagons, 15 miles per hour." When we think of a modern first-class road, with its four tracks, its 80-ton engines, and its fine vestibule cars, the development of this line of public works does indeed seem amazing.

The importance of the experiments and investigations which the State Board of Health have inaugurated will probably do much towards solving many uncertain questions in water supply and sewage disposal. In fact, it is in this original method of dealing with the engineering questions of the day that the American engineer is entitled to the greatest credit, and in this good work, wherever it may be going on within this commonwealth, we may rest assured that members of this Society are playing an important part.

In this country we are further removed from the conventional ruts and traditions which hamper many other nations in dealing with these subjects.

In an address before the Institute of Civil Engineers, Mr. George Barclay Bruce, after an extended tour in the United States, speaks as follows on this very point:

"The impression on my mind throughout this trip has been one almost of envy towards the engineers of America for having a land so big to deal with in the practice of their profession, and at the same time I feel continually disposed to congratulate them upon the spirited way in which they grapple with difficulties and the successful way in which they have overcome them."

In a recent report to the French Government, a commission of engineers, sent to the United States to examine their public works, make use of the following language:

"One easily recognizes in the great works of the American people those qualities which have made them the first engineers in the world."

At the last meeting of the British Association for the Advancement of Science a number of American inventions were exhibited which called forth the heartiest applause. No less an authority than Sir William Thomson, the learned electrician, said: "Never have I seen an exhibition of applied science surpassing this in interest. I can see that its outcome is to be a revolution in our industries."

It is certainly gratifying for us here, to-night, to feel that engineers, as fully as other professional men, are carrying forward the standard of their faith, and that in Massachusetts as well as elsewhere important work is accomplished for the welfare of man. In this reasonable pride, in which I am sure you all join, I am careful not to say that ours is the best work, or that nowhere else in the world is such and such work being done. The broader our view, the less inclined are we to arrogate too much to

our own working horizon. Another source of gratification arises when we remember that the field for the engineer's work is constantly widening, and a full consideration of the fact may well lead us to take a hopeful view of the future. So wonderful are the changes now taking place in the profession that specialities are rapidly forming and decided success, as in some other professions, can generally be best attained by him who follows one road to the end. In this connection it has often occurred to me that there is one practical way to advance the interests of our profession in which as a Society we might perhaps profitably engage. There is no reason why in the appointments made by public authorities, particularly in the matter of public works, the engineer should not be considered as well as the members of other professions. The engineer's training fits him particularly for filling places requiring the exercise of the administrative faculties. We may consider it an excellent beginning in this direction when the Governor recently appointed three engineers to sit on a commission, all of whom are members of our organization.

We may well have confidence in the future, because the preparation for the engineer's work will be more thorough. The advances in metallurgy, chemistry and physics will contribute their quota to the highest achievement of the engineer. As the rewards increase, the quality of work done will also increase, and in striving to lift the veil it is difficult to imagine the great advances which the good time coming has in store for the next generation. I have a firm conviction in regard to the great work which this Society is destined to accomplish. As the strength and power of our membership increases, so will the resources and influences of our Society increase. I believe we have already reached a point where we may reasonably look forward to the time when our successors will be installed in a house of their own possession, which will be something of a club-house as well, and where the members may always find an attractive home. This truly will be a little millennium, but whether it comes in our generation or not, I hope as we stand shoulder to shoulder in the endeavor to advance our professional standard we shall still have for the Boston Society of Civil Engineers something of the feeling and enthusiasm of the school-boy which always leads him to give a hearty cheer for his Alma Mater.

SOME TESTS OF FULL SIZE ANGLE IRONS.

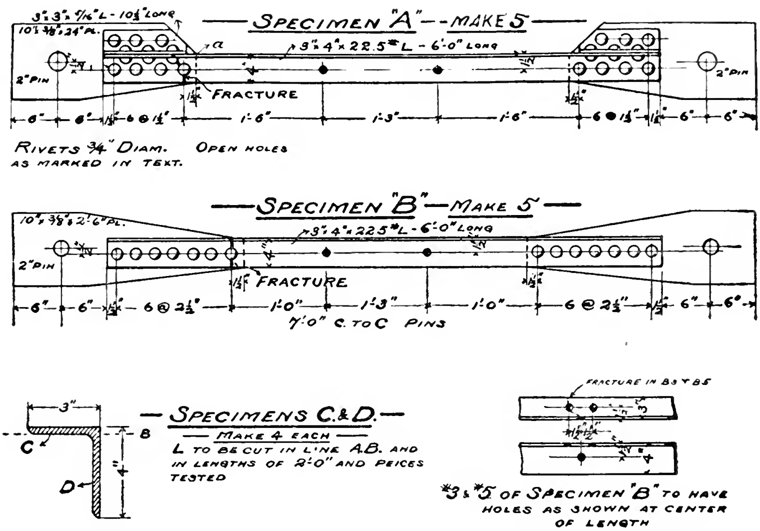
By Charles F. Loweth, Member of the Civil Engineers' Society of St. Paul.

[Read October, 1888.]

In a recent structure, the question arose as to the actual value of angle irons in tension, and the writer had some tests made to cover the case, as far as limited time and means would allow. It is with some hesitancy that these tests are here presented, as the design of test pieces is not as varied, and the number of tests sufficiently large, to cover the debated ground even approximately. The aim was to determine what such details, as are not infrequently met with, are actually worth. They are

offered, therefore, for what they are worth, and with the hope that they may lead to a more complete series hereafter.

The material tested was ordinary angle iron, 4 inches $\times$ 3 inches $\times$ 7.5 pounds per foot, about $\frac{21}{64}$ inch thick, all being made at the same time and place by the New Jersey Steel and Iron Company, and corresponding in quality with the iron intended for use in the structure. The angles from which the specimens *C* and *D* were cut were unintentionally made slightly heavier than the others, but otherwise of the same rolling, and fairly represent the quality of the material in the other specimens. The form and size of test pieces are shown in the plate. There were five pieces each of *A* and *B*, and four each of *C* and *D*.



The angles were in each case connected by the larger leg with the pin plates and the connecting rivets placed as near the back of the angle as practicable (nearer than ordinarily done in practice) for the purpose of reducing the eccentricity in line of strain as much as possible. The riveted specimens were made pin ended in order to definitely fix their length and also that they might more readily deflect as required.

The tests were made in New York at the Fairbanks testing laboratory on their 200,000 pound machine. The specimens were all prepared at the same time, though tested on two different dates. The accompanying tables give a record of the tests.

The net area in specimen *A* is taken as 0.12 square inch less than that of *B*. Net area of *B* equal 1.98 square inches.

Under strain both angle and plates bent, opening the joint at *a*, as was expected, and indicating very plainly the large bending due to the eccentricity of strain.

It was expected that specimens *A* would prove much stronger than specimens *B*; that their strength was so low comparatively is

SPECIMEN A.

No.	Date. 1887.	Open holes.	Ultimate strength. Total.	Ultimate strength. Per sq. in. net.	REMARKS.
1	Sept. 5.	15-16 in. diam.	66,800	35,910	Broke through end rivets in both legs.
2	"	1⅛ in. diam.	49,080	26,400	
3	Nov. 2.	1 in. diam.	71,280	38,280	
4	"	1 in. diam.	56,100	30,300	
5	"	1⅛ in. diam.	75,240	40,450	

Average ultimate strength per square inch, net area......................34,270

SPECIMEN B.

No.	1887, Date.	Diam of open holes.	Ultimate strength. Total.	Ultimate strength. Per sq. in.	REMARKS.
1	Sept. 5	15-16 in.	67,960	34,300	Broke through end rivet hole.
2	"	1⅛ in.	61,520	31,070	" " "
3	Nov. 2	1 in.	74,320	37,500	Broke through open holes in body of angle at small flaw in surface of 3 in. leg.
4	"	1 in.	55,600	28,080	Broke through end rivet hole.
5	"	1⅛ in.	72,240	36,480	Broke through open holes like No. 3, except no flaw in angle.

Average ultimate strength per square inch of all specimens......................33,486
Average ultimate strength per square inch of Nos. 1, 2, 4, which broke in detail.31,150

SPECIMENS C AND D.

No.	1887. Date.	Area sq. in.	Per sq. in. elas. limit.	Per sq. in. ult. strength.	Fracture.
1	Sept. 5.	.928	39,920	50,520	Fibrous.
1	"	1.584	34,530	48,385	"
2	"	.914	34,950	50,220	"
2	"	1.640	34,100	49,020	"
3	"	.919	32,750	48,160	"
3	"	1.580	37,400	53,900	"
4	"	.975	34,680	50,140	"
4	"	1.588	33,225	47,860	"

Average ultimate strength, all specimens....................49,775 lbs. per square inch
" " " 3 inch legs........................49,760 " " "
" " " 4 " " ....49,791 " " "

probably largely due to greater bending produced in the angle due to the more abrupt transformance of strain into it from the tin plates.

The open holes were for the purpose of inducing fracture in the body of the angle other than in the detail, and succeeded only in the case of specimens *B*, Nos. 3 and 5, and these, very strangely, showed the highest ultimate strength.

As a whole, the tests indicate that the strength is largely reduced

where the line of strain does not concide with the centre of gravity of the material. In practice, this lesson has generally been more readily acknowledged in respect to compression than to tension members. The same lesson may be learned from a recent test of a full size railway bridge floor beam as described in a paper by Mr. Boller, C. E., and published in the Transactions of the American Society of Civil Engineers for May, 1888, where the bottom flange angles of the beam failed at a strain of less than 15,000 pounds per square inch. In the transactions of the same society for September, 1884, Mr. G. Pegram, C. E., records a tension test of a 4 inches × 4 inches × ⅜ inch angle, 4 feet 8 inches long, having only one leg connected by rivets to the end plates and which broke at only 23,030 pounds per square inch net section, while a flat 4 inches × ⅜ inch × 4 feet 8 inches long, cut from a piece of the original angle and somewhat injured in preparation for testing, showed a strength of 40,100 pounds per square inch net section.

There is still another lesson to be learned, namely, that rivet holes staggered or alternating in the legs of an angle, even though spaced as in this case, one and one-half inches apart, largely decreases the strength, for it is observed that each specimen *A* failed in a similar manner by fracture through the adjacent holes in the two legs. The spacing of holes so close together, even if alternating, as in the specimens, is a common fault in iron-work design, most noticeable perhaps in the case of bottom flanges of built beams and girders at the ends of flange plates.

It would be profitable to continue this series of tests to ascertain the relative strength of angles of different lengths between end connections; also the strength of angles in pairs, placed back to back, with separators at intervals to prevent deflection.

THE WINDING OF DYNAMO FIELDS.

By Francis E. Nipher, Member of the St. Louis Engineers' Club.
[Read March 20, 1889.]

There are two methods of winding the fields of dynamos. One method is applied when the armature has been constructed and mounted upon the frame, and is ready for the field coils. The proper wire to wind upon the field can then be found by determining the constants of the machine when operating, its field being excited by a trial coil.

The other method seeks to compute the output from a working drawing of the machine. The present paper will deal to some extent with both of these methods.

If a dynamo is to be designed for a definite kind of work, for instance, to run a definite number of lamps in parallel, then the current which it is to furnish and the difference of potential of the mains is known.

The armature is then to be designed to satisfy the following equation:

$$E = \frac{z_1 \; N n}{10^8 \times 60} \qquad (1)$$

where z_1 is the number of lines which the armature core will carry, N the number of windings of wire around the core, and n the number of revolutions per minute. The value $\frac{n}{60}$ is, therefore, the number of revo-

lutions per second, and 10^8 is a factor which converts centimetre-gramme-second units of potential to volts.

When fully saturated, annealed charcoal iron wire will carry 150,000 lines to the square inch, and iron disks 132,000.

For a Gramme ring of iron wire the value of z_1 would be

$$z_1 = \frac{2\,S \times 150,000}{2} \qquad (2)$$

Here S is the net section of iron in the armature ring. Each half of

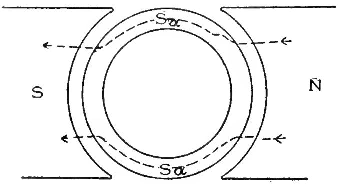


Fig. 1.

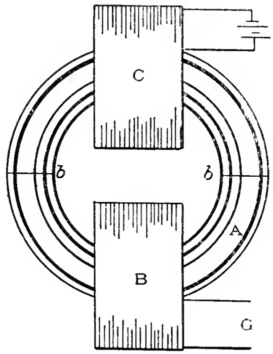


Fig. 2.

the ring carries only half of the lines, as shown in Fig 1. Hence the total section of the iron is $2\,S$. The iron ought to be only half saturated when the machine is carrying its normal load, and hence the quantity must be again divided by 2.

If, for example, the armature is to give 102 volts at 750 revolutions, and furnish 450 ampères, then by (1) and (2)

$$102 = \frac{150,000 \times 750 \times N\,S}{10^8 \times 60}$$

As the current divides in the armature, its conducting wires must be large enough to carry 225 ampères. It is customary to allow at most 3,000 ampères per square inch of section in armatures. Hence the conductors must be no smaller than one-twelfth of a square inch in section.

The problem then reduces itself to the winding of enough turns of wire of the known capacity upon an iron ring which must be large enough to carry them, and of such section that it will carry enough lines at 75,000 lines per inch when the dynamo is carrying its working load and running at the predetermined speed. It is important to have as small a distance as possible between the armature core and the pole-piece. These considerations being properly heeded, it is easy to make the drawing of the armature by a few trials.

The section of the field should be somewhat larger than that of the armature, for two reasons: First, hammered wrought iron will carry at saturation only 108,000 lines per square inch. Secondly, some of the lines produced in the field leak around the armature. The number of leakage lines depends upon the shaping of the pole-piece, and is, there-

fore, different for different machines. The number of lines lost varies from $\frac{1}{4} z_1$ to z_1 in different machines. The leakage lines ought not to be over twenty-five per cent. of those produced in the field. Hence the section of the iron circuit of the field should be $\frac{150}{108} \cdot \frac{4}{3} = 1.8$ times the section of the iron circuit in the armature. If there are two magnetic circuits in the field, the last rule refers to the sum of the sections of those circuits and to the sum of the two cross-sections of the armature ring. By this means it is aimed to secure half saturation in the field, each square inch carrying 54,000 lines of force.

If the machine is already constructed, the gauge of wire for the field coil may be selected by the trial method. This method will be illustrated by a determination made by the author on an eight-pole dynamo of the Schuckert type.

The armature was designed to deliver 80 ampères. Trial coils of 41 turns each were wound upon the eight spools.

The field was separately excited, and the total E. M. F. of the armature was found for various exciting currents i, and for speeds n, ranging from 500 to 700 revolutions. The observed values of E, n and i were found to satisfy fairly well the formula of Frölich,*

$$E = \frac{a\, n\, i}{1 + b\, i} \tag{3}$$

where

$$a = 0.0031$$
$$b = 0.0056$$

Here $a = a'\, S$.

Where $S = 328$, or the total turns on the field, and a' depends on the geometry of the dynamo and the quality of iron used in its construction. Also $b = \sigma \times 328$, where σ is the so-called saturation co-efficient. Hence

$$\sigma = \frac{0.0056}{328} = 0.000017.$$

Suppose it were desired to wind this dynamo as a shunt machine, for operating glow lamps requiring 98 volts, 0.64 ampères.

The machine furnishing 80 ampères would thus feed 125 lamps.

The armature resistance was 0.046 ohm. The resistance of each lamp will be $\frac{98}{0.64}$, and of 125 lamps would be $\frac{98}{125}$ $0.64 = 1.22$ ohms. The resistance of the working load should be a mean proportional between the armature resistance and the field resistance. Hence the latter may be taken as 23.5, or about 500 times that of the armature.

The resistance of the field and the brush potential being now fixed, the current through the field is also fixed. It will be $\frac{98}{23.5} = 4.17$ amperès.

Hence, when the machine is finally wound, its working conditions will be represented by (3), as follows :

$$E = \frac{\frac{0.0031}{328} S\, n \times 4.17}{1 + 0.000017 \times 4.17\, S}$$

* Thompson, Dynamo-Electric Machinery, 2d ed., page 278.

Since the armature resistance is 0.046, and the current in the armature is 84.17, the fall of potential in the armature will be $84.17 \times 0.046 = 3.87$. Hence the value of E must be $98 + 3.87 = 101.87$, or 102 volts. Substituting in the last equation, and solving for S,

$$S = \frac{2,600\,000}{n - 184} \tag{4}$$

It is thus seen at once that the number of turns on the field is simply a function of the speed. If n were 184, S would become infinite, or the iron must be completely saturated in order to get an E. M. F. of 102 volts.

If the dynamo were run at a speed of 2×184, the iron would be half saturated, as will appear from the following considerations:

Equation (3) may be put in the following form:

$$E = \frac{a' \; S \; n \; i}{1 + \sigma \; S \; i} \tag{3^1}$$

The iron would be saturated by making $S\,i$ infinite, which would give for a limiting value of E,

$$E = \frac{a' \; n}{\sigma}$$

If now $S\;i$ were made equal to $\frac{1}{\sigma}$, (3^1) becomes

$$E = \frac{a' \; n}{2 \; \sigma},$$

showing that when the magnetizing power of the field coils is made equal to $\frac{1}{\sigma}$, the number of lines is one-half the number required to produce complete saturation.

If (3^1) is reduced to the form of (4) it becomes

$$S = \frac{\dfrac{E}{a' \; i}}{n - \dfrac{\sigma \; E}{a'}} \tag{4^1}$$

If, therefore, $n = 2 \dfrac{\sigma \; E}{a'}$

$$S\,i = \frac{1}{\sigma}$$

Since in the machine under consideration i is to be 4.17 and $\sigma = 0.000017$, the total turns on the field to produce half saturation is $S = \dfrac{1}{\sigma \; i} = 14,000$, or on each spool 1,750.

We turn now to considerations of a purely geometrical character, in order to learn what must be the size of the wire used in winding the field.

The resistance of the whole field being 23.5 ohms, we have on each spool 2.93 ohms. If L be the length of this conductor in feet, r_o its radius in inches, and K' the resistance in ohms of a copper wire one inch long and one square inch in section, then

$$2.93 = K' \frac{12 \;\; L}{\pi \;\; r_o^{\,2}} \tag{5}$$

In the computations which follow K' has been assumed 0.00000069, which is a little too small for safety under working conditions. A better value would be 0.00000075. In the table below L is computed from (5) for conductors of various sizes, from No. 18 to No. 11 of Brown & Sharpe's gauge.

The field cores of the dynamo were cylindrical in form with a spool radius R_o of 2 inches and a length l of 7.2 inches. If R' is the external radius of the helix when wound, the insulation thickness being assumed 0.004 inch for all wires, then R' can be computed with sufficient precision from the following formula:

$$12\, L = \frac{\pi\, (R'^2 - R_o{}^2)\, l}{4\, (r_o + 0.004)^2} \qquad (6)$$

The values of R' are given in the fourth column below.

Similarly the number of turns on each spool can be found from the formula:

$$\frac{S}{8} = \frac{l\, (R' - R_o)}{(4\, r_o + 0.004)^2} \qquad (7)$$

The number of pounds w of copper for the eight spools can also be readily found from the data already known, and is entered in the table below for each gauge of wire.

In case the field magnets are not cylindrical in form, the data here computed can always be worked out by some method which should readily suggest itself.

Finally, by solving (4) for n and substituting the values of S corresponding to each gauge, the speed required to give 102 volts and 84.17 ampères with this machine is computed. These values are entered in the column headed n.

The values of L, $\frac{S}{8}$, w and n as a function of the wire radius in thousandths of an inch are shown in the diagram.

B. & S. gauge.	r_o in.	L ft.	R' in.	$\frac{S}{8}$	w	n
—	0.0202	457	2.1	424	17	950
17	0.0226	569	2.2	517	28	812
16	0.0254	718	2.3	635	45	695
15	0.0285	905	2.5	772	71	606
14	0.0320	1,114	2.7	909	110	541
13	0.0360	1,439	3.0	1,098	180	482
12	0.0404	1,815	3.4	1,275	286	439
11	0.0454	2,288	4.0	1,451	455	408

The output of the machine and the power wasted in the armature and field is the same for all these wires for which the table above is computed, provided that the other imposed conditions are satisfied. The choice of wire is limited on the one hand by the cost of copper and the increasing diameter of the bobbins, which makes the outer layers less effective when large wires are used, while for the smaller gauges the limitation is due to the increasing armature speed, and to the necessity of avoiding overheating of the field.

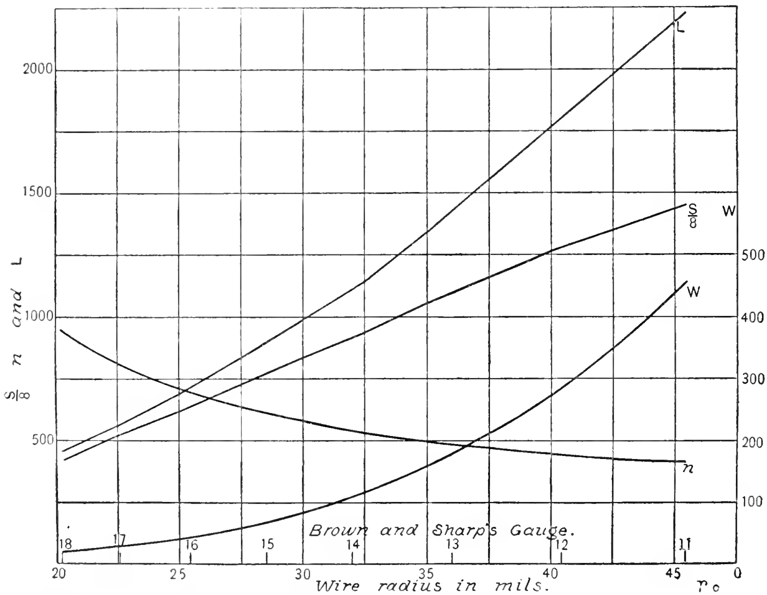
A rule given by Munro and Jamieson, and recommended as safe, is that the current density in spools should be for wires under 2 millim-

etres in diameter. 5 ampères per square millimetre. If r_o be the radius in inches and i the current in ampères, this is equivalent to

$$r_o = \frac{\sqrt{i}}{100}$$

This would make a No. 18 wire, B. and S., the smallest wire for a current of 4.17 ampères. Others give the rule that one square inch may carry 1,000 ampères. This would make a No. 13 wire the smallest that could be used. The latter rule is apparently not so near to American practice as the former one.

It appears from the table that even with the largest wire there computed, the number of turns on one spool will be 1,451, while with a current of 4.17 ampères, 1,750 turns are required to produce half saturation. It follows that this machine might be wired throughout for a higher output.



The other method of proceedure is based upon a determination of the number of lines of force which a dynamo of known construction should furnish. Before proceeding it will be necessary to make a few preliminary explanations.

In Fig. 2, A represents an iron ring stamped or turned out of homogeneous metal. Two coils of wire, B and C, link with it, the one being connected to a battery and the other to a galvanometer having a heavy needle. When the circuit in C is closed, the ring is magnetized, but no polarity is shown around the ring if the coil is wound closely around the iron. The lines of magnetic force are conducted around the iron ring in closed curves. Their presence is shown by the momentary induced current in B when the circuit is opened or closed. The number of lines in A can be determined by measuring the throw of the galvanometer

needle, the method being analogous to that of the ballistic pendulum in determining the velocity of rifle shots. The constants for B and G can be determined by revolving B suddenly through 180 degrees in a field of known strength. The angle of throw can be found with precision by reflecting a beam of sun-light from a mirror attached to the needle upon a divided scale, which is photographed during the throw. The division where the spot of light comes momentarily to rest can thus be found with very great precision. The number of lines increases with the magnetizing power of the helix C. The magnetizing power is proportional to the current in C and to the number of windings. It is measured in ampère turns. If the iron ring is made larger in circumference or smaller in section the number of magnetic lines diminishes. It appears that the lines meet with resistance, as a current of electricity does in a conductor. The relation between number of lines z, magnetizing power P and resistance R, is expressed by a formula analogous to the one representing Ohm's law for electricity:

$$z = \frac{P}{R} \tag{8}$$

The resistance of the iron R is proportioned to the length of the iron circuit, and inversely proportional to its section, or

$$R = K\frac{L}{S}$$

Where K is the magnetic resistance of unit length, having unit section. The value of K is about 700 times as great for air as for iron. If the iron ring has a break at $b\ b$, the number of lines carried by the circuit is less than if the ring is continuous. A sheet of paper inserted between the iron surfaces at b also very greatly increases the resistance. By varying the width of the gap at b the relative resistances of iron and air can be found. It is also found that K is not constant for iron, as it becomes more and more saturated. The value of K increases to ∞ for complete saturation. Mr. Kapp finds that the value of K is represented by an empirical expression, as follows:

$$K = K_o \frac{\tan\left(\frac{\pi}{2}\sigma\right)}{\frac{\pi}{2}\sigma}$$

Where K_o is the value of K when the magnetizing power is zero, or when $i = o$ in coil C, and

$$\sigma = \frac{z}{Z}$$

Where z is the number of lines actually carried by the iron, and Z is the number which would be carried if the iron were saturated or if $i = \infty$. Z is the limit to which z approaches as i increases. Both K_o and Z can therefore be found from observations with finite values of i.

The value of Z can also be found for armature iron by observations on the dynamo itself. In (3) if $i = \infty$

$$E = \frac{a\,n}{b}$$

If the armature approaches saturation before the field does, this value of E may be substituted in (1), from which z_1 may be found, which is Z for that particular armature.

The following values of K_0 are given by Kapp for iron:

Wrought iron	$\frac{1}{3000}$
Cast iron	$\frac{1}{2000}$
K for air is	0.24

The values of the tangent function are:

σ	$\dfrac{\tan\frac{\pi}{2}\sigma_1}{\frac{\pi}{2}\sigma_1}$	σ	$\dfrac{\tan\frac{\pi}{2}\sigma_1}{\frac{\pi}{2}\sigma_1}$
0.1	1.008	0.6	1.460
0.2	1.034	0.7	1.785
0.3	1.081	0.8	2.449
0.4	1.156	0.9	4.466
0.5	1.273	1.0	∞

To apply these values to a Gramme dynamo, let

P_1 = ampère turns required to drive z_1 lines through the armature and clearance spaces at the pole-pieces.

l_a = average length of iron circuit in armature core in inches.

l_2 = average length of air circuit in each of the two clearance spaces.

S_a = net section of iron in the armature ring, so that the z_1 lines are carried by $2\,S_a$ square inches.

S_2 = area of pole-piece face in square inches.

$z_1 = \sigma_1\, Z_1$.

Then by (8)

$$P_1 = \left(K_1 \frac{\tan\frac{\pi}{2}\sigma_1}{\frac{\pi}{2}\sigma_1} \frac{l_a}{2\,S_a} + K_2 \frac{2\,l_2}{S_2} \right) z_1 \qquad (9)$$

This value of P_1 is the magnetic pressure or potential at the pole-pieces.

Some of the lines produced by the field leak around the armature and are of no value in producing E. M. F.

This leakage circuit may be considered as one in parallel with the armature, and analogous to the equations for a divided circuit we mav write

$$P_1 = \xi\,\rho \qquad (10)$$

Where ξ = the number of leakage lines, and ρ = the air resistance to the leakage lines.

The value ρ is a complex quantity, and will differ for machines of different type. For machines of the same type, it will vary inversely as the linear dimensions of the machines precisely as in the ground plate of an electric circuit. If the value of ρ is known for any type of machine of given dimensions, the value of ξ may be at once computed for any machine of that type, since P_1 is known from (9). It will be assumed

that ρ is not known, and is to be determined with ξ, for a Gramme machine.

Let

P_2 = the additional number of ampère turns required on the field to drive $z_1 + \xi$ lines through its iron circuit.

$z_2 = z_1 + \xi$ = lines carried by the field.

L_f = length of either of the two iron circuits of the field, from pole-piece to pole-piece.

S_f = section of one of the iron circuits of field in square inches.

Then

$$P_2 = K_1 \frac{\tan \frac{\pi}{2} \sigma_2}{\frac{\pi}{2} \sigma_2} \frac{L_f}{2 S_f} z_2 \tag{11}$$

Where

$$\sigma_2 = \frac{z_2}{Z_2} \tag{12}$$

Substituting this value of σ_2 in the denominator of the tangent function, the values of z_2 will cancel.

Let P represent the total ampère turns on the field, or

$$P = P_1 + P_2$$

P can be found from the actual observation on the machine. Hence by substituting this value of P_2 in (11),

$$\tan \frac{\pi}{2} \sigma = \frac{\pi S_f}{K_2 L_f Z_2} (P - P_1) \tag{13}$$

From this equation σ_2 is readily found and z_2 can then be computed by (12).

The value of $\xi = z_2 - z_1$, which substituted in (10) gives the value of ρ.

The Gramme dynamo to which these equations will be applied was a small machine built some years since by a New York company. It was a series machine and was wound for a ten ampère current. The net section of the armature core was 1.4 square inches. Hence

$$Z_1 = 150{,}000 \times 2.8 = 420{,}000.$$

For any assumed value of σ_1 the value of z_1 is then found, from which E can be computed for 1,000 revolutions by (1), the armature winding being known (60 sections of 20 turns each).

When driven at 1,000 revolutions E was also represented by (3), as follows :

$$E = \frac{14.2\, i}{1 + 0.18\, i}$$

from which i is found for the various values of E and σ_1, as is shown in the table below.

For computing P_1 the additional data needed are

l_a = 8 inches.
S_a = 1.4 square inches.
l_2 = $\frac{14}{16}$ inch.
S_2 = 33.5 square inches.

For computing $\tan \frac{\pi}{2} \sigma_2$,

$$L_f = 30.3 \text{ inches.}$$
$$S_f = 5.8 \text{ square inches.}$$

Hence $Z_2 = 108,000 \times 11.6$
$= 1,252,800.$

Turns on the four spools of the field = 1,036.

σ_1	z^1	E	i	P_1	P	$P-P_1$	σ_2	z_2	$\xi=z_2-z_1$	ρ
0.1............	42,000	8.4	0.66	567	691	124	0.12	150,000	108,000	0.0052
0.2............	84,000	16.8	1.50	1,135	1,554	419	0.34	426,000	342,000	0.0033
0.3............	126,000	25.2	2.60	1,709	2,694	985	0.60	752,000	626,000	0.0027
0.4............	168,000	33.6	4.09	2,181	4,237	2,053	0.78	977,000	809,000	0.0027
0.5............	210,000	42.0	6.32	2,885	6,547	3,662	0.88	1,102,000	892,000	0.0032
0.6............	252,000	50.4	9.88	3,510	10,235	6,725	0.93	1,165,000	913,000	0.0038

The value of ρ here is as near constant as could be expected when the other features which this table shows are considered.

It will be observed that the field is constantly more nearly saturated than the armature, although its section is four times as great. This is due to the fact that the crescent-shaped pole-pieces which embrace the armature lack only 1.9 inches of being in contact at their terminals, while the two air spaces between pole-piece and armature core sum up 1.7 inches. The field is short-circuited around the armature. The computations, therefore, serve to show how badly this machine was designed, rather than to determine the value of ρ.

It will be a very great service to the profession if some well equipped school will determine this value for the several well defined types of machines now in the American market.

RAPID TRANSIT IN BOSTON.

By Henry Manley, Member of the Boston Society of Civil Engineers.

[Read February 20, 1889.]

The Boston in question is not that area included within the municipal limits only, but that larger Boston which includes the surrounding cities and villages within a radius of perhaps 10 or 12 miles, and including a population of about 800,000 people, whose interests are those of Boston, and a large number of whom daily ride to and from their places of business in some public conveyance.

I assume that more rapid transit than now exists is imperatively called for, and shall not go into statistics to prove the assumption correct, though the figures that show it are interesting and instructive. It has been shown in other cities that after a population of about half a million has been reached, unless improved means of transit are provided, that the city fails to grow at the rate it had before maintained. The numerous petitions for charters for elevated railroads in our streets, which are annually presented to the Legislature, and persistently and ably urged, show that there is a demand for it, and the efforts of the West End Street Railway in first considering cable roads, and then adopting and

constructing electric roads, show that they are alive to the fact that the present means of transportation are insufficient.

I assume further that no system of rapid transit which proposes to carry passengers on the same plane as that on which the ordinary travel is carried, will suffice in Boston. Our streets are very narrow and crowded, and are now mined with all the kinds of pipes and conduits known to the engineering profession, and I may add that they are filled with forces and compounds of mighty strength and of incompatible qualities and habits.

Municipal councils have wisely limited the driving of horses to a speed of six miles an hour. I assume that no good reason can be shown why vehicles in the streets, propelled by any power, should be allowed a greater speed.

Six miles an hour is not rapid transit.

If it be urged that in wide suburban streets, with spaces especially reserved for the purpose, greater speed may safely be permitted, I reply: at best, a series of grade crossings will thereby be established which are opposed to public policy, and in time, and after a sufficient number of accidents, cannot fail to receive the public condemnation.

I further assume that elevated roads are entirely inadmissible in the older and more crowded streets of Boston. There is not room enough now for teams, foot passengers, light and air. I will not deny that in cases of dire necessity, in the wider streets, they may possibly be allowed, but not in the central part of the city. Electric and cable surface roads are very useful improvements. I assume that all they can do for us in Boston is to take the place of and do the work now done by horses, and that they will thereby improve the service for the passengers and diminish the cost to the proprietors. They cannot give us rapid transit.

The three most successful systems of rapid transit in existence, so far as I am informed, are in New York, London and Berlin. New York has elevated steam railroads in the public streets. London has steam railroads underground, and Berlin combines the regular surface steam railroads of the country with an elevated road on private land across the city.

I assume that the New York and London systems are inadmissible in Boston, the first for reasons already given. The second because the city is already too low and that proper drainage would so increase the expense as to render the method impracticable. This does not deny that underground sections of roads may be built under Beacon Hill, and supplement an overhead system to their mutual advantage. The third, or Berlin system, I consider to be admirably adapted to Boston.

Boston possesses a network of steam railroads radiating in all directions, and I assume that in all cases the local passenger business forms perhaps the most profitable item in the grand total of the business done by the roads. Each of these roads brings thousands of regular daily passengers to the city—and leaves them all at one point on the outskirts—when their objective points are scattered over perhaps ten square miles of surface.

An examination of the map shows that the terminal points of these

roads are, roughly speaking, all on the circumference of a circle of about one mile in diameter. The scheme that I wish to propose is briefly this: Let some able financier do for the steam railroads what has been done for the horse railroads—that is, let them pool their local passenger traffic, bridge this narrow vacant space with an elevated road, connecting the several surface roads. Then let each surface road select a convenient point on its line and rise, by an incline, to the level of the elevated road. The new elevated road to be preferably built on private property, but whether on private ground or on public streets, or in tunnel under Beacon Hill, forms no essential part of the scheme. This road may be a belt line, or not, but in any event it is to be a continuous line, with no butt-end stations. The precise route for this road and the locations for stations would be governed by a thousand considerations of cost, policy, politics and engineering, and could be determined only after careful and exhaustive study.

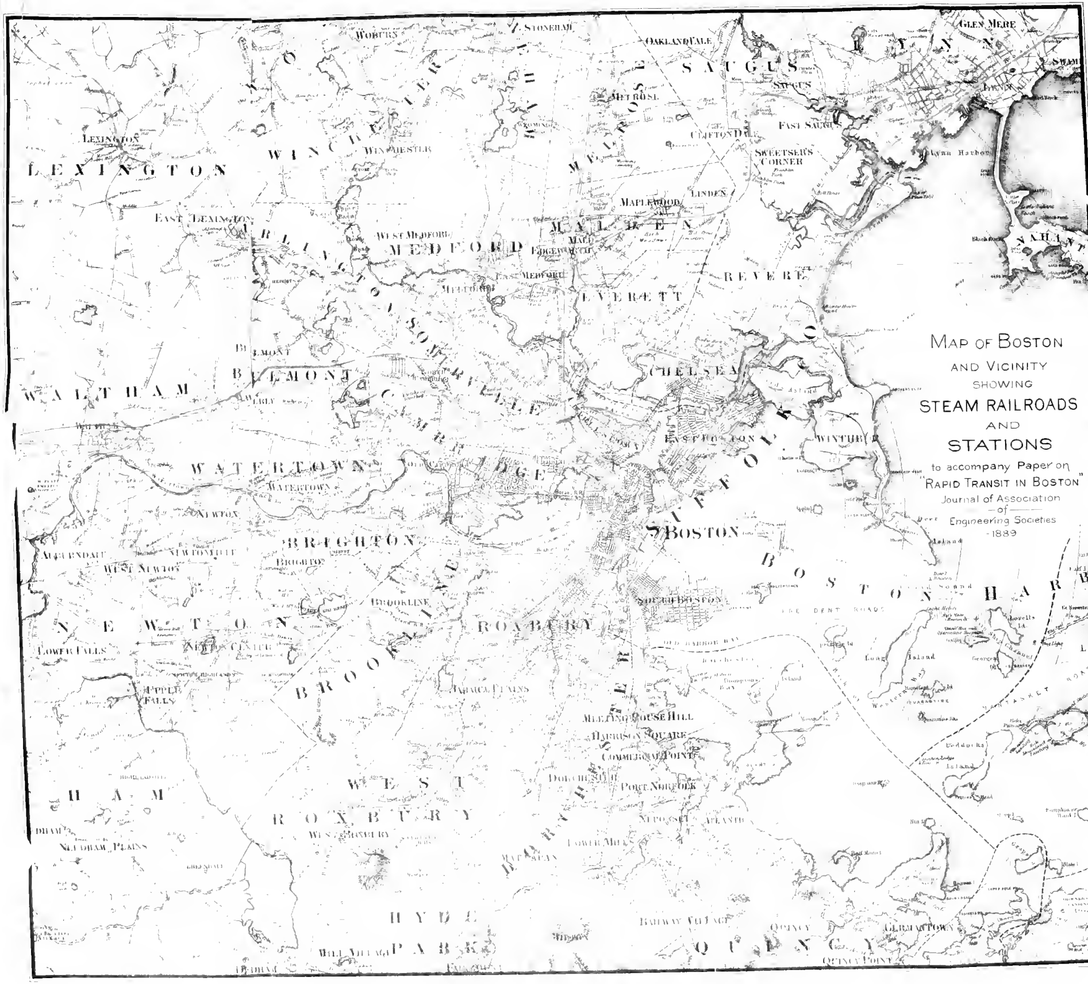
The success of the road would then depend upon its management. I would let no train be stopped and turned around in the central part of the city. For instance, let trains made up at South Braintree run through the city to Reading, and vice versa. Another train made up in Somerville might run through to Dedham. In short let all trains coming to the city pass entirely through the city and turn round on the further side.

The objections to the scheme may be of a financial or of an engineering character, or may relate to the management of the long distance and freight business. The financial objections I do not propose to go into at this time further than to say that plenty of capital appears to stand ready to build elevated roads without the enormous advantage that the possession of the surface roads already built would give. It also seems reasonable to suppose that a combination of this character could obtain from the State and city all the privileges that would be granted to any new company.

The engineering objections can certainly be readily overcome with sufficient capital, and as applicable to this point I will read from the *Engineering and Building Record* of Feb. 4, 1888, and following numbers, extracts from the very full and interesting description of the elevated road in Berlin, which will show what has been built in that city. It should be understood that in Germany all railroads are owned and managed by the government.

"The considerations which led to the construction of the Metropolitan road were, in the first instance, of a strategetic nature. When the Prussian State Department took the work in hand, it desired to make complete connections between the lines running to the east and those running west, in order to give a possible mobilization of the army the assurance of absolute success.

The railroad is an elevated structure, crossing all streets and roads above their level. Outside of the city limits, beyond the junction depots, its tracks slope down and connect with the general railway system. Within the city limits the style of the structure was prescribed by the city authorities, and it was built as an arched viaduct; the approaches at each end were embankments. At the east end, where the property was more valuable, the embankment was contained between retaining walls; at the west end it was not. It may be remarked here that the prescribed style of an arched viaduct almost invariably coincides with the interests of the railway company, as a comparative estimate of the cost of the viaduct within the city limits


MAP OF BOSTON
AND VICINITY
SHOWING
STEAM RAILROADS
AND
STATIONS
to accompany Paper on
"RAPID TRANSIT IN BOSTON"
Journal of Association
of
Engineering Societies
1889
LEXINGTON
WALTHAM
WATERTOWN
BELMONT
MEDFORD
MALDEN
EVERETT
REVERE
CHELSEA
SAUGUS
BRIGHTON
ROXBURY
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compared favorably with an embankment on account of the small amount of property to be acquired, and as between an embankment containe l between retaining walls, it compared favorably on account of the possibility of utilizing the arches of the viaduct for business purposes. The road is a four-track road throughout. The two northern tracks are reserved for local traffic, while the two on the south are traversed by passenger trains from the trunk and suburban lines, the two services being absolutely distinct.

Construction, Viaduct, Termini.

It is a sinuous line, which crosses the city from east to west, following practicably the major axis of the ellipse formed by the belt line, built some years before, which surrounds the town connecting with all railroads which it intersects. It is separated only a short distance from the Spree River, which it crosses three times. Its length between the two termini (*Schlesischer* and *Charlottenberg*) is 12,145 metres (7.55 miles). The radii of the curves vary from 300 to 500 metres. The grades are from 2 to 8 in 1,000.

Of the entire structure, 12,145 metres long, 7,964 metres, inclusive of depots and stopping places and stone bridges, was built as arched viaducts; 1,823 metres, inclusive of street crossings and iron bridges, was built with iron superstructure; 675 metres, inclusive of the Silesian junction depot, was built as embankments contained between retaining walls, and 1,683 metres, inclusive of the depot Charlottenberg, was ordinary embankment.

On account of the low elevation of the tracks of only six metres above the street, no construction could be considered excepting masonry, and where exceptionally iron construction was employed local reasons were the governing causes.

The viaducts are of uniform construction throughout, excepting that the distances between the piers slightly vary. The form of the arch is always a segment of a circle. On account of the great cost of the viaduct careful preliminary work preceded the final adoption of the plans, and the piers and arches were carefully and scientifically proportioned. * * *

Street Crossings.—The number of street and road crossings between the terminal depots is 65, and, with the exception of a few of the small lanes, which could be carried through the arched openings of the viaduct, they were constructed as iron bridge on massive masonry abutments.

Besides the two terminal depots at Schlesischer and Charlottenberg, the Metropolitan has eight stations. Three of them are so constructed that they are used for both the trunk line and local traffic.

Baggage is only received at the stations used by the trunk lines. The baggage rooms are also upon the ground floor, the baggage being raised to the platforms by hydraulic elevators.

The construction of the termini is of brick masonry.

For the local traffic the trains are run during the week at ten minutes intervals in each direction from five o'clock in the morning to midnight. On Sundays and holidays they are run under five minutes headway. The mininum number of cars in a train is 8, the average weight 11½ tons.

The stops at the stations average thirty seconds each; and the average speed of the local traffic is about fourteen miles per hour, including stops and slow running.

The figures given as the total first cost of construction are divided as follows:

Right of way, $8,377,362; construction, $9,482,868; total expenses, $17,870,230.

The third point, the management of the combined class of business, would require careful treatment. In Berlin a magnificent central union station is provided, and that and the terminal stations are used for long distance travel. Either a union station or a comparatively small station for each road would be required. In any event, with the two classes of passenger traffic separated, the management would be much simplified and the enormous terminal stations and grounds now in use would be thrown on the market. Butt-end stations, as they are termed, are not in favor with railroad men. The terminal station in large cities consists of a combination of offices, hotel, and train shed, and serves to collect th stream of passengers into ponds to be drawn off at leisure. If the stream

is kept running, no ponding can take place. In other words, instead of making your patrons gather into one large station, drive the train around the town and pick them up from almost their own office doors.

The most improved practices of the elevated roads elsewhere should be introduced, both upon the elevated and flat sections. There is no special virtue in an elevated road *per se* over one upon the level. Methods that facilitate travel upon one will equally facilitate travel upon the other. I know of no good reason why light trains of short cars, with ample exits and entrances, powerful engines that can start and stop quickly, platforms of stations on a level with platform on cars, and stops of 8 or 10 seconds instead of 40 to 60 seconds can not be provided as well upon roads on the level as upon roads in the air.

With the construction completed as outlined, with convenient stations within a few minutes' walk of every point in the city, travel will become easy and pleasant. To illustrate: In coming into town I ride seven miles upon steam cars. I am landed at the farther end of a station more than 800 feet long, and while, if the train kept in motion, it would land me at my destination in two more minutes, it takes me as long to walk the remaining distance in town as it has done to ride the seven miles in the cars.

The arrangement proposed will allow trains from the northern roads to cross the Charles River at a sufficient height to satisfy the law and the orders of the government concerning the bridges over that river, and the construction of the expensive union station now in contemplation could be avoided. The roads could sell their valuable land in the city now used for storing passenger cars and engines, and buy more further out, where land is cheaper. An inspection of the map will show what a brilliant series of circuit lines could be formed if all the roads were under one management. But the greatest gain to the roads, if they take advantage of the opportunity now open to them, will be the acquisition of the monopoly forever of rapid transit in Boston.

The welfare of the city will be greatly affected by the adoption of the system. It will give opportunity for people of limited means to live in the country, and have the advantages of fresh air and freedom from overcrowding. It will greatly enhance the value of suburban real estate. It will discourage the building of tenement and apartment houses, and encourage the building of houses with grounds about them. It will allow of and encourage social relations between residents of opposite sides of the city, which are now so much discouraged by poor transportation. It will enable the great public to visit easily, and readily, the parks and places of resort at the seaside. In every direction its effect will be of the most far-reaching character.

Let us glance at the probable course of events if this opportunity be not embraced. One elevated railway already possesses a charter, and many more are knocking at the doors of the Legislature. The people need the accommodation, and sooner or later, with more or less restriction, the charters will be granted. A series of roads, with conflicting interests, will be constructed, each doubtless relieving to some extent the wants of a particular section, but falling far short of the benefits of a comprehensive system. The roads built first will follow the lines of

heaviest travel, later they will be extended to parallel the existing steam railways, and as they will give better service, by delivering their passengers nearer their destination, they will take the lion's share of the travel, and the public will pay for two sets of roads, and get half service for double fares.

The point of double fares, which I have not before touched upon, is well illustrated by some lines of doggerel from *Puck*, which I will read in conclusion :

THE ROAD TO RUIN.

He was a man in business on big Broadway,
And his home was in Brooklyn, abaft the bay;
And this was his route for to gain that blest shore—
First the "L," then the bridge, then the "L" once more.

The church of his love was just three car rides,
And his club was the same, and another besides;
While his seven small children went every day
To seven different schools, seven miles away.

To the store or the market, to the play or the slide,
Wherever they went they had always to ride;
And this, kept up for a brood of nine,
Took a river of gold that would drain a mine.

His fortune at first was a million and o'er,
And his business had brought him a billion or more;
But 'tis sad, and 'tis sour, and 'tis mean to recall,
How the street car companies got it all.

He succumbed, as succumb all mortals must,
And his bones were committed to Greenwood dust;
And a plain little headstone the epitaph bears:
"This man was busted by street car fares."

By Albert H. Howland, Member of the Boston Society of Civil Engineers.

[Read February 20, 1889.]

It is some ten years since the establishment of the elevated railroad system in New York. This effected so great a revolution in local passenger transportation that many other cities naturally expected to soon enjoy equal improvements. After the problem had once been solved for New York, it seemed a wonder that capitalists and engineers had not so co-operated as to accomplish the solution earlier, for building a bridge over a street so as to form an elevated railroad is likely to be no more difficult than building one over a river.

Some of the differences between the situation in New York and that here are quite obvious, but I think many of them are not given sufficient weight in forming opinions ; so that, while Boston is waiting for a great revolution in passenger transportation, its attention is diverted from some moderate improvements that might be made with great benefit, and perhaps give us facilities equal to those of New York ; in fact, it may well be claimed that they are now equal or even superior in some respects.

In New York the City Hall, Post Office, Custom House, etc., are at the south end of an island 10 miles long and 2 miles wide; its nearest steam

railroad (previous to the opening of the East River Bridge) was about 1½ miles distant from City Hall, and the nearest without transfer to and from ferry was 3 miles distant; the only connection by bridges to the main land was at the north end.

On the other hand, Boston already has the terminal stations of eight steam railroads within one-half or three-quarters of a mile from City Hall, accommodating without ferry transfer the population in all directions. Adding the branches within ten miles makes the number of roads practically twice as great. There are stations, too, by the score within what for this purpose we may consider city limits.

In order to facilitate comparison of some of the elements that enter into the question, I have gathered some data as to distances, population, area, etc., and present them in tabular form herewith. I have aimed to make the comparisons on an approximately even basis, but various complications make it impossible to be at all exact; for example, my figures generally are meant to refer to transit *without change* from start to destination, but I have included the New York Central Railroad and some smaller ones (though their terminals are miles from City Hall), excluded the East River Bridge, and included the Revere Beach road; furthermore, some census figures are a good deal out of date.

For short distance travel there seems but little doubt that street railroads at the surface will maintain their position. They are cheap, go everywhere, take the passenger near his starting-point and land him near his destination, receive and land the passenger at any point on the street, and save climbing and descending stairs. On the average these advantages may be counted as equal to ten minutes in favor of street cars; or for a passage within one or two miles of City Hall elevated roads will offer little if any advantage over surface roads. Improvements in motive power will be a gain to them as well as to elevated roads. As regards the cost, as indicated by stocks and bonds, the amount for our street railroads is about $75,000 per mile, while for the New York elevated roads it is about $1,500,000, divided about equally between stocks and bonds, the ratio in the comparison being 20; what the ratio would be if both were rendered anhydrous I make no attempt to decide. The elevated railroads carry about half a million passengers per day, which is a good deal more than all the street railroads in Massachusetts carry.

Comparing the data in the table (which apply only to the territory within 10 miles of City Hall), we see that in New York the population per square mile at different distances is from about 4 to 24 times as great as here; per mile of railroad, 3 to 9 times; per station, 1 to 8 times; the area per mile of road, about $\frac{9}{10}$ to $\frac{3}{10}$ as great; the area per station, $\frac{2}{10}$ to $\frac{3}{10}$ as great; length of railroad per station, $\frac{3}{10}$ to $\frac{9}{10}$ as great: and time of passage from City Hall there and from terminal stations here (omitting passages within the two-mile limit) is about one-third *less here* than there, even with only our present roads.

In view of the conditions as we find them here, it seems to me that we are likely to reap the most benefit from a given expenditure by the construction of a short elevated road through the city, making connection between the present terminal stations on the north side of the city and

those on the south, and then running trains from the suburbs on one side to those on the other. Such a scheme might be supplemented by the addition of branches, and very likely in some cases by elevated roads or roads that are elevated, surface, depressed or in tunnel, as the special cases require. The conditions seem to be too complicated for one simple solution. An important point is that no plan should be entered upon, unless it is thoroughly considered, that will be out of harmony with the roads that furnish the chief means of transportation at present, either as to gauge or type of rolling stock that will be admissible; also that the roads that now penetrate nearest to the centre should not hastily abandon the terminal part of their roads. Such a connecting road would naturally be owned by a separate corporation controlled by the present roads, and very likely some degree of pressure would be needed from the Legislature to set the wheels going.

To be sure the future may have improvements in store that we little dream of now; very likely many of us have devoted considerable thought to some pet schemes of our own, but such possibilities are of little account in considering what improvements are feasible under circumstances as they now exist.

Such a road would relieve the present terminals and the street railroads: it would give the principal centres, such as the markets, financial institutions, wool, leather, furniture, retail shopping and other interests, quick communication with nearly 200 suburban stations, and would furnish us what I might designate as the missing link.

Comparison of Rapid Transit Facilities in Boston and New York.

This table is intended to apply to such territory (within the limits designated) as is supplied with passenger transportation by steam without transfer: but there are some exceptions as to transfer. The time of passage (in the last column) is from the terminal station in Boston and from the vicinity of City Hall in New York to the *more distant* point given in the column of distances on the corresponding line.

	Distances on radii from City Hall, miles.	Population estimated.	Area, sq. miles.	Length of railroad, miles.	Number of stations.	Population. Per square mile.	Population. Per mile of railroad.	Population. Per station.	Area. Per mile of railroad, sq. miles.	Area. Per station, sq. miles.	Length of railroad per station, miles.	Time of passage, minutes.
BOSTON.	0 to 2	280,000	7.1	15.4	19	39,000	18,000	15,000	0.46	0.37	0.81	3 to 13, say 7
	2 to 3	145,000	9 7	14.0	14	15,000	10,000	10,000	0.69	0.69	1.00	7 to 16, say 11
	3 to 5	135,000	36.2	35.6	61	3,700	3,800	2,200	1.02	0.59	0.58	10 to 33, say 17
	5 to 10	185,000	166.0	101.7	111	1,100	1,800	1,700	1.63	1.50	0.92	16 to 46, say 30
	0 to 10	745,000	219.0	166.7	205	3,400	4,500	3,600	1.31	1.07	0.81	
NEW YORK.	0 to 2	630,000	4.4	11.0	40	143,000	57,000	16,000	0.40	0.11	0.27	10 to 12
	2 to 3	240,000	2.1	4.6	13	114,000	52,000	18,000	0 46	0.16	0.35	15 to 18
	3 to 5	380,000	4.2	11.6	22	90,000	33,000	17,000	0.36	0.19	0.53	25
	5 to 10	320,000	14.7	27.2	45	22,000	12,000	7,000	0.54	0.33	0.60	45 to 65
	0 to 10	1,570,000	25.4	54.1	120	62,000	29,000	13,000	0.47	0.21	0.45	

[NOTE.—The close correspondence in some points between the views stated above, which I have held for many years, and those presented by others is quite marked. I believe the conclusions were reached entirely

independent, and that the agreement is the natural result from the conditions of the case.]

Discussion by Members of the Boston Society of Civil Engineers.

[February 20, 1889.]

By Eliot C. Clarke.

Undoubtedly the scheme outlined by Mr. Manley would benefit greatly those persons who wished to cross the city proper in going from one suburb to another. But there must be comparatively few such travelers; not the twenty to fifty thousand daily who would be needed to pay operating expenses and interest on the cost of such a road. The great bulk of travel hereabouts is done by the one hundred thousand persons, more or less, who leave their homes in the morning to go to their places of work and who return in the evening.

Now it seems to me that most of these persons already are provided with reasonably rapid transit. Those who live within two miles of their place of business can reach it in thirty minutes, either by walking or by riding part way in the horse cars. Those who live within six miles, and not more than one-half mile from a railroad station, also can reach their work in about half an hour. This is no longer time than the average New Yorker spends in similar travel *via* his elevated roads. The nine terminal stations in Boston are all within ten minutes walk of the business centre of the city. An elevated road through the city, at best, only could reduce the average distance to be walked one-half, and its stations would not be so commodious as those we now use. The Providence division of the Old Colony Railroad now runs fifty suburban passenger trains each way daily, and could double this number if necessary. So could the other roads. Would it be a real benefit to most business men and women to lessen slightly the little daily exercise they now take by walking?

An elevated railroad is, of necessity, an unsightly nuisance, and especially would it be so in the narrow, crooked streets of Boston. Building one here only could be justified by extreme need.

I recognize that there are populous suburban regions situated midway between existing railroads, whose growth is retarded by the need of more rapid transit, and whose people would be much benefited by having elevated roads leading to the city. But it would not be practicable to reach all such districts by such means. All things considered, it seems to me that the most practicable thing to do would be to build, at frequent intervals, surface railroads, horse, cable or electric, at right angles to the existing steam railroads, as feeders for the latter, and have a single or coupon ticket good for a ride on the two roads.

By Thomas Doane

Mr. Manley proposes an elevated railroad through the city of Boston from the north to the south side, and preferably on and over private grounds to be bought, and not through the streets.

He would connect with it the steam railroads approaching Boston.

The present stations of the roads are upon the margin of the city, at the water's edge, and they could not rise to the necessary elevation with-

out raising their roadways across both Fort Point Channel and Charles River. This would involve the loss of the use of their present stations and grounds, and involve large expense.

Mr. Manley proposes, as I understand, a single line, but with a sufficiency of tracks. It would require a great amount of land for way, and a large area in the very heart of the city, at enormous cost. The four railroads at the north side of the city are now proposing a union station covering eight acres to accommodate its 250 daily train arrivals and departures. To include the other roads would bring the total number of trains to near 500.

This necessitates a train, during 15 hours of the day, every $1\frac{8}{10}$ minutes, and at certain times of the day several trains per minute.

Arriving trains can be unloaded in a minute or two, but departing trains, for long distance travel at least, must be in waiting about fifteen minutes.

It hardly seems possible that the entire railroad business can be done in a single station. The necessary size in the needed locality would require vast sums both for land and buildings, and the narrow streets known to exist in the required locality would be gorged beyond endurance.

The long travel passing through Boston must make a change of trains at this station. The cars and engines of one road would hardly be permitted to pass through Boston and go to other destinations over other roads.

An arrangement *might* be made for suburban travel to pass on continuous trains through the city and return, but this travel from one suburb to another without a stop over in the city is very light. If coming to the city for the day it would be necessary to accommodate it by stops near the entrances to the city, as well as at a central station. This would very much interfere with the rapid transit feature of the project.

Business has adjusted itself to the present position of affairs. Those mechanics and laborers who reside in the suburbs, have their business location largely around the margin of the city. They naturally go into the suburbs over that railroad which has its station nearest to their places of business. That is, the North End people go and come over the Fitchburg. Boston & Maine, Eastern and Boston & Lowell Railroads: the West End people by the Boston & Albany and Providence, and the South End by the Old Colony. It is but about one mile across the city from North End stations to the South End stations. By an elevated road numerous stops in this mile could hardly be made without blocking the road.

Professional men more largely go to the centre of the city.

It seems to me that it is clearly easier, and better. and quicker, to distribute the people from numerous stations than from a single one, or from such stations as would be permissible upon a single line. Most people would be able to reach their destinations much quicker by walking than by riding, even were a conveyance immediately ready to take them up. and in addition they would save their 5 cents fare each way, which is important to most people.

That passenger service through the streets is slow and unsatisfactory is admitted, and that it will in some way be bettered can hardly be

doubted. Even now there are many projects for elevated roads in Boston, most of which have abandoned the idea of using steam as a motive power. Electricity and cables are talked of, and compressed air engines are used abroad.

There is another scheme for which I have made surveys and estimates of cost. It is a belt line running about Boston at a distance of five or six miles, and reaching from East Boston to South Boston. Its length would be about 22 miles. It was arranged for a first-class double track road, and had no grade crossing of either highways or railroads. All the steam railroads were, however, connected with it by easy inclines, making it possible to transfer both passengers and baggage in their cars, as well as freight, from any road to any other. Such a road would cross and connect with all steam railroads and suburban horse railroads, and give the necessary accommodations between suburban towns.

It would pass near to almost all of the public parks and the various cemeteries, and make easy access to both north and south sea shore.

It would also make a most delightful pleasure excursion in the summer.

It seems to me that some such plans as these would solve our passenger problems much more satisfactorily and at much less cost, both to the corporations and the passengers, than would a single elevated line directly through the city.

There is one other objection to an elevated 4 to 6 tracks road through the heart of the city. The *noise* occasioned by the moving freight and passenger trains would be so great and continuous as to utterly destroy the utility and value of all property in the neighborhood, both for office and residence purposes. The dust nuisance would also be insufferable.

By Clemens Herschel.

The arguments brought here to-night against the system of rapid transit for Boston, proposed by Mr. Manley, are completely answered, as it seems to me, by the experience of the city of Berlin with just such a system. Three years ago, when in Berlin, I improved the opportunity to study the practical operation of its elevated railroad, and of its belt road, and, as a result, came away very much impressed with the perfect working of both. The old railroad end stations are used principally as outward stations for long distance passenger travel; one of the elevated railroad stations forms the principal inward passenger station for all the roads, for the simple reason that more people with luggage wish to stop there than at any of the other elevated stations. While this station and all the other elevated railroad stations are used indiscriminately, and in either direction of travel, by all local trains; in contemplating which picture of the passenger circulation it must not be forgotten that the elevated railroad has four tracks, and, in modern parlance, is run for all it is worth.

Freight traffic is interchanged between the several roads, mainly by means of the older belt road, though it also has some passenger trains upon it.

I agree with Mr. Manley that the Berlin system appears better adapted to the needs of Boston and vicinity than any other system yet tried in other cities. The thing to be aimed at is to create a line or lines of least

resistance, from any point within a radius of, say, 20 miles of City Hall to any other point within the same area. Carrying Mr. Manley's simile still further, the requirements with regard to the possible passenger traffic within this area are not unlike the requirements of a water distribution system within the same territory. Only that the main tendency will be to pulsate from all over this territory to a central circle of one mile diameter, and out again, twice in twenty-four hours. This granted, what should we say to a system of pipes for water distribution which was chopped off on approaching from any direction this one mile circle, which had the main pipe come to so many dead ends on reaching the confines of this circle, and which then called upon the users to force the water across and into this central portion through small pipes by horse-power pumps; or, to judge from the remarks of some of our conservative members, would fain have the people carry the water beyond the dead line and these dead ends in pails.

To my mind the difficulty to be encountered is one of organization and finance alone. The fact that two of our members, independently studying the subject, and writing upon it, have come to identical conclusions, is to me very weighty. And, as I have said, experience in Berlin justifies the conclusions they have reached. I believe a proper study of the problem would leave little doubt as to the proper remedies to be applied. But to acquire those remedies becomes more difficult. We are, unfortunately, as I view it, not organized to carry on works of such magnitude by public enterprise, unless it be with respect to building sewers, in which line the doctrine of scare can be and repeatedly has been successfully invoked to urge them on, thus creating the public sentiment in favor of, and from some source necessary, to the construction of such very great public works.

In the case of gas-works, street railways, and, as now proposed, local railroad passenger travel, in the matter of good highways, new waterways and other needed public works, we are either dependent for the execution of comprehensive works, of the kinds enumerated, upon the powers of comprehensive consolidations, or must do without them altogether. So soon as large consolidations have taken place, and plenty of examples could be cited to prove it, works which previously had been only discussed and wished for, became at once matters of course, and in a very short space of time were made beneficent realities.

So in this case. As stated by Mr. Manley, and as it certainly seems to me, a pooling by all the railroad lines ending in Boston, of their local passenger traffic, with agreements for a common use of connecting elevated or other roads, would readily create works which would very perfectly fill the needs of Boston in the line of her increased growth and of her progress; at the same time rendering unnecessary, nay more, preventing the harm that would arise, from the chartering and the construction of many disjointed pieces of elevated railroad of manifold make.

BY EDWARD W. HOWE.

The scheme proposed by Mr. Manley is a grand one, and one that would undoubtedly be of great benefit to a large portion of our people, at least to those residing on the lines of present steam railroads.

There has been a great demand during the past ten years for a system of rapid transit of some kind. Now from whom has this demand come, and what is it that is demanded? Have the people living on the lines of the steam railroads at distances of five miles and upwards been complaining of the difficulty of reaching the city or of passing through it? Have the residents of Malden been petitioning the legislature to grant them better facilities for reaching Mattapan, or have those of Weymouth been crying aloud that their happiness depended on being able to reach Waltham without change of cars? Or have the people of these localities felt themselves greatly aggrieved because they could not go from their homes to their places of business without great inconvenience? I think that most of you will admit that these are not the sources from which the great cry for "rapid transit" has come.

If you will look at the map you will see that South Boston extends eastwardly from the lines of the Old Colony and New York & New England Railroads for nearly two miles, City Point being about three miles from City Hall by the present lines of travel. This section is occupied by a population of about 60,000, who have no means of reaching the city proper except the horse cars. Again, there is a section between the New York & New England and the Providence railroads, varying from one to two miles in width, and extending a distance of four miles from City Hall, all of which is densely populated. This district is also dependent on horse cars for reaching the heart of the city, with the exception of a few residents living near the six stations on the above-mentioned roads; and so badly are the people accommodated that large numbers are in the habit of taking a 10 or 15 minutes' walk to the steam railroad only to be carried to the stations in town which are still a long distance from their places of business; they do this rather than suffer the delay and discomfort of a 30 to 60 minutes' ride in the horse cars.

Again, on the other side of the city there is a district between the Boston & Albany and Fitchburg railroads which is from two to three miles wide, and includes nearly the whole of the city of Cambridge with its 60,000 inhabitants which are even in a worse situation. To these sections may be added portions of Brookline and the Brighton District, Charlestown, Chelsea and East Boston.

Now, as I understand the matter it is the people of these sections who have been the signers of the various petitions for improved methods of transportation in the city of Boston, and who would consider it a great boon if they could be carried from their homes to within a distance of one-half to three-quarters of a mile of the City Hall in the same proportion of time to distance that Mr. Manley can from his home.

It seems to me that these citizens who are obliged to go back and forth between their homes and their business every week day in the year, in all kinds of weather, and be subject to all sorts of delays and suffer the discomforts of crowding, etc., should have their demands satisfied before the public should be put to the expense that Mr. Manley's scheme would involve for the purpose of making it possible for a person in Dedham to make an evening call on a friend in Chelsea, on a stormy evening, without being obliged to raise his umbrella or put on his overshoes.

Now, the question arises, what will satisfy the demands of these people. I would suggest that two lines of elevated railroad be built, one from City Point to Harvard Square, Cambridge, or beyond, and the other from Franklin Park, in Roxbury, to Charlestown Neck. Through trains could be run on these lines from end to end. Of course, they would cross at some point in the heart of the city, where the grades could be separated and a transfer station provided; by this means passengers could go from either of these four sections to either of the others with only one change, and that under cover. Then, if it was desired also to accommodate the patrons of the various steam roads, a line could be built from the Providence station to the New York & New England station, passing the Boston & Albany and Old Colony stations. This would cross the lines of road from Roxbury and South Boston, where transfer stations would be built. At the northern end of the city the line from Charlestown could be made to pass sufficiently near the proposed union station of the northern roads to afford easy means of transfer from them.

If it should ever be found desirable to unite all the roads so that trains could be run from one to the other, as is proposed by Mr. Manley's plan, then the tracks of each could be connected with the lines I have described, and so everybody would be made happy.

This seems to me to be beginning at the right end and spending our strength in furnishing something that a very large part of our population are suffering for, before providing a system of which the most that can be said is that it would be very convenient.

By Charles H. Parker.

In discussing the question of more rapid transit for the people of Boston, it is well to admit at once its desirability.

There is also but little doubt that great efforts are being made to solve the problem. The eagerness manifested by different combinations to secure legislative charters for special plan shows, in a general way, that each projector looks upon the matter as quite easy, from his standpoint, the matter of details being comparatively simple. It is quite easy to generalize, but it is only when we come down to particulars that the magnitude of the task becomes apparent.

To give to Mr. Manley's opening address on this subject a fair discussion, will require much thought and time, and as the object of his paper is to open up the subject, it seems to me the way to approach it is to bring forward the difficulties and objections from every point of view, in the hope that our society, as practical engineers, may as a body add something useful to the solution of this problem. While, therefore, many of us may, in the discussion, appear nominally as opponents, it will only be in appearance, in order thoroughly to investigate every point.

In the first place, let me ask how much is Boston to-day behind other cities? Is it any? There is hardly a city in the United States with a suburban population scattered over such a large territory, that is supplied with as good and extended a system of steam railroads, or one that lands the bulk of its passengers within a circle of so small a radius. The average time spent by the suburban citizen in walking from the terminal

of his road to his place of business need not exceed 13 minutes. I say the *average*, because it is the question as affecting *all* that must be considered. For the sake of light, air, elbow-room, our passenger considers it no great hardship to spend twice this time at the home end of his journey. He would still do this in connection with any other system.

The 10 or 12 miles intervening between the home depot and terminal is covered at the rate of 20 miles per hour on the local, and 30 miles or more on the express, If one desires rapid transit he can time his daily movements to use the express, so that the distance of 12 miles from the suburban depot to one's place of business can be covered in an average time of 33 to 35 minutes. Now, where can we find a city in which as much rapid transit can be found? Even the city of New York, much more favorably located and shaped—being a long, narrow strip of land, with its three or four parallel lines of double-tracked elevated road—does not do it. For an equal distance in miles lengthwise the island, a passenger travels slower than one does entering Boston *via* our steam roads from the suburbs.

To be sure he has more frequent trains, but this is because the homes are concentrated on the long, narrow island, served by two or three parallel lines, instead of being scattered around the the concentric rings of a wheel, intersected and served by 14 or 15 radial roads, all running to the hub.

In proportion to the total number to be carried, these 14 or 15 radial roads, counting branches, run in the aggregate as many trains as the New York system.

The difficulty seems to be, not so much the means of rapid transit, as the failure of the suburban dweller to concentrate on the spokes of our wheel. The locking up, by speculators and investors holding for a rise, of desirable lands and estates adjacent to lines already in existence, prevents this concentration, as well as the establishment of depots at shorter intervals.

It forces the would-be suburban dweller away from the immediate vicinity of these lines, to points where prices are lower; then, after he locates, he ever prays for another road or branch to come through *his* location in order to give him better facilities and increase his values.

This much is presented as regards the surrounding territory. Now it is proposed by Mr. Manley to unite all these different systems, either by agreement to pool or consolidation, for the purpose of establishing a connecting link between the whole and reach other points not now reached by the present system, and to secure in conjunction rapid transit for the suburbs as well as the city proper.

Let us examine this question :

The present railroad system of Boston from the south and west is practically an underground or under grade one, and so far as the New York & New England, the Boston & Albany (and inside the city limits, the Boston & Providence) are concerned, must remain so. The Old Colony and the exceptional points on the Boston & Providence will in time wholly become so. The systems entering from the north and east seem destined in time to become an elevated system. Further consolidation or exchange of terminal stations to secure freedom from

present railroad grade crossings will not interfere with such an elevated system.

To connect all the Boston systems by an elevated system, the location of the connecting link must be far enough out on the Southern and Western systems to keep entirely clear of their present undergrade system, and the whole Northern and Eastern must be changed to an elevated system.

From this it seems that this proposed system of elevated connection must enter the city proper on the north side, *via* some of the present lines crossing the Charles River.

Assume this to be the case. Our connection with East Boston, Chelsea, Malden, Charlestown, is feasible with a branch line, or by lines already existing, and our connection with Charlestown, Somerville, Cambridge, across Charles River again, and by some feasible route around through the western suburbs to the Southern roads, and enter the city again *via* Dorchester, South Boston, across Fort Point channel, as an independent elevated road (which you must do in order not to destroy the present undergrade system), thence by any one or two feasible routes to the northern end.

Allow that all this can be done. Also, if you please, the passage through the city proper so as to reach that part of the city occupied by the business and working people and the shoppers. Allow double tracks with trains both ways—keep in mind we are after the rapid transit, either on foot, riding, any way. The question is to get there quickly, with the least trouble and expense.

Now, how many people living on the present lines of steam roads would use such a line if in a hurry? Could they reach their place of business as quick? I think not. They would keep to the present lines and take the 12 or 13 minutes walk from the present terminals.

Assume that many not now reached would be. That much desirable property would be developed. Cannot the same be accomplished by extensions of our present systems, and at less cost? That this necessarily circuitous route will give us more rapid transit is an open question, with the odds seemingly against it.

Leaving this external connection of our present systems for further discussion, let us turn attention to an internal one, or to that part of the above within city proper limits, whether controlled or not by present roads.

Allow, if you please, that change of cars at terminal stations, to elevated, was made possible. Whether or not the increased accommodation in the suburbs is brought about by a new elevated road or by the improvement and extension of present systems, the passenger when he strikes the city proper limits is no nearer his place of business than the present terminals land him. He has got to get through the city or into it.

The situation is much as follows :

We have a 600 or 700 acre lot, about a mile long, and at its widest part nearly a mile wide, bounded by (starting at the Providence depot) Elliot street, Kneeland street, Atlantic avenue, Commercial street, Causeway street, Leverett street, Green street, Court street, Tremont to West street Gate, thence via the Common to the Providence depot.

Into this 600-acre lot it is only a question of a few years, at the present rate of increase, before we will pour, during three hours in the morning and out of it during three hours in the evening, probably 250,000 people, or, in round numbers, 75,000,000 per year. Allow that two-thirds of this number will either walk or be carried by other means of conveyance, and give the other one-third to our elevated system, that is 25,000,000 per annum traveling each way. Now, with its broad, straight avenues and stations at wider intervals than we should demand for rapid transit, the present heavy and cumbersome system of the New York L's has a maximum capacity of 5,000,000 per annum per train-mile, so that, with our twice 25,000,000 carried one way, we will require ten miles of track to handle it. You may say my figures are extravagant. I think not, for the future needs of the Boston of 1,500,000 people. Still, halve the amounts, and call it five miles of track.

Now to land your passenger within an average walk of less than thirteen minutes, you cannot go around the circumference of your lot. You must go through and across it, because there is where he wants to go. Your road must be the great artery from which he can branch right or left, and still he will have an *average* of five or six minutes to walk. And if you can find a place to locate this five miles of track, or say two lines of double track one mile each, with one mile for siding, switches, crossings, or what else, or a figure 8 double track road crossing itself under Beacon Hill—how much quicker, including stops, unloading, starting again, getting up to speed, can you land him at a point where his *average* walk of five minutes, added, will get him to business ahead of the fellow that started to walk his average twelve or thirteen minutes from present terminals?

If he wanted rapid transit he would not mount your elevated road, but trust to "Shanks' mare." The small percentage that wish to go completely across the lot is but of little moment as affecting the whole.

The territory seems too small, its winding ways too crooked and narrow, its real estate too valuable. Boston's business must spread out. Our 600-acre lot must be given up in time to wholesale business. More street widening through unimproved property will yet have to be done. Our teams, carriages and foot passengers, must have these thoroughfares to get across our lot, and it may be even a question of time when the present surface roads must keep outside, and their passengers will find more and more, what many *now* realize, that rapid transit across it means that they must "hoof it."

When the retail and manufacturing business of the city spreads out, even far outside the location of the present terminals of our railroad system, to the south and west over our underground system, and to the east and north under an elevated system of the present lines, we shall then realize, better than now, the benefits of our present terminal locations, and perhaps receive the congratulations of our sister cities at our escape from the hasty adoption of the elevated system.

As engineers we must, of course, not oppose progressive methods, but it is just as obligatory upon us to keep conservative until it is shown clearly that such a course is also progressive. Our motto should be "Hasten slowly."

By M. W. Oliver.

The paper by Mr. Manley on "Rapid Transit in Boston" presents a subject that, I think, should be of much interest to this Society. It is certainly as much a legitimate local field for our interest as the subject of water-works or sewerage or any other public work. I am glad that it has been presented, and hope the Society will not abate its interest in the matter until the subject has been lifted out of the ruts of a horse-car track and the problem of rapid transit in and about Boston has been fully and properly solved.

In the evolution of all such matters there generally comes a time when a new departure seems to be required, and let us give the credit of initiating a new departure in this matter to the West End Railroad Company, to whose kindness and courtesy we, as a Society, are indebted for our first ride by the power of electricity, and an opportunity to examine their works to the extent of our curiosity in January last.

But without disparaging the merits or conflicting with the interest of anything that is being done, for it is a great step in the evolution, I think it is perfectly apparent that the time has come when a broader and more comprehensive view of the whole subject should be taken than ever has been heretofore, both from the point of municipal and general railroad interest, and also from an engineering point of view. And I think we may very properly say that from an engineering point of view it seems that something yet more comprehensive, thorough and permanent is desirable, and that it would be wise to make a forecast, so as to utilize to the best advantage, and secure harmony with, what has already been done or is being done, and what will be required in the near future.

The scheme of a regular full-sized railroad overhead across the city to connect all the railroads on the north side of the city with all the railroads on the south side of the city, may be a scheme of such magnitude and boldness as to seem to some persons visionary, and perhaps unnecessary and not adapted to facilitate rapid transit, especially in the central part of the city. But it deserves candid consideration and need not conflict with any interest. All the surface roads that can possibly be allowed will always be wanted. No favorite route or patent pet chimerical methods of construction is proposed, but a clear cut idea to have one grand through road across the city, both for passengers and freight, so located and constructed according to the best engineering methods as to serve the intermediate needs, and be the trunk line of a comprehensive system that shall be susceptible of extensions to meet future growing requirements.

In this connection it should be remembered that the location and grade of some of the steam railroads through the near suburbs of the city, especially through Cambridge and Somerville, are very objectionable and dangerous, and that a remedy will be imperatively demanded in the near future, and the changes of location, or the elevation of these roads, may be no small factor to be considered in solving the problem of such permanent work within the city, as proposed.

I consider that this scheme, or its equivalent in general features, should be the ultimate object of any plan that pretends to be compre-

hensive enough to meet the necessities for any considerable time after its completion. But as necessities are now pressing, it is apparent that a scheme of such magnitude cannot be even commenced in season to answer present needs.

In view of ultimately having a comprehensive and harmonious system of elevated roads, it must be apparent that fragmentary parts should not be allowed to be built on favorite choice routes, and perhaps of chimerical methods of construction and odd gauge of track, that could not be made ultimately a part of a harmonious system. If such fragmentary and miscellaneous construction were allowed, there would very likely result a confusion—worse confounded than the approach to the city of the present steam railroads.

By Arthur L. Plimpton.

I would emphasize the fact that the plan Mr. Manley offers has this objection to it, namely: It would not accommodate the wide areas of population which lie in between the existing surface steam roads, which areas increase practically with the distance from the centre of the Hub, *unless numerous* and objectionable branches should be constructed. And it certainly would not pay on these branches to run *trains* with sufficient frequency to make what could be called rapid transit. For I hold that in estimating the time that it takes for a business man to go from his residence to his place of business, you should include the time he spends in *waiting* for the conveyance, and not merely the time consumed while being carried.

The problem is how to take people rapidly from any part of the city to all other parts. Therefore, you must have *lines running everywhere.* This, in effect, is what the street cars do; and if we could increase with safety their speed, and avoid the annoying blockades, the desired end would be accomplished.

With electricity as a motor, there will be no difficulty in running at the desired speed on all of our avenues, excepting those included in that part of the city proper north of Dover street. Take Washington street, Tremont street, Huntington avenue, Beacon street, Main street in Cambridge, Main street in Charlestown, and Broadway in South Boston, these are all of sufficient width to allow the same rate of speed, with safety, that is attained on the cable roads of our Western cities, and which so perfectly solve the problem of rapid transit. With electricity as a motor, there can be a slight increase in the running of the cars, even in the above exceptional part, owing to the fact that the car can be started so much quicker, and is under such perfect control, that when there is a clear track for a short distance advantage can be taken of it.

Now, in my opinion, the public, as a whole, will be satisfied with such an improvement as the above would be, should it be adopted on all the street cars. But, if the demand should be so great for more rapid transit across the city proper, that even an elevated road would be welcome on Washington and Tremont streets (where it certainly must go if it is going where the people want to go), then I would strongly recommend the following plan, which has been suggested to me, since the meeting, by

a gentleman of large experience in such matters, and one whom I consider to be most ably fitted to see what all the results would be of any radical change. He considers it the most feasible way of solving the plan and so it seems to me.

We have brought the cars in, for example, over the wide part of Washington street at good speed; at this point a certain part of the cars, which we will call the through cars, would be lifted by means of elevators at once to the level of the elevated tracks, and after starting would not stop again until a station, at, perhaps, Summer street, was reached. The elevators would be located off the streets, and the power would be the same to run the cars on the level, the elevator, and the car on the elevated track.

That is the whole story: there is no need of elaborating it. It explains itself. It limits the objectionable elevated road to just such part of the city as, from its narrow streets, forces us into it. It avoids the long inclines which Mr. Manley's method necessitates, which would so change the grades of crossing streets that the damage to property would extend so far from the line of the structure that it would cost untold millions before it could be carried out. It would be a *part of the system* that now covers some 250 miles of track, and which will continually be added to as our city grows.

By C. Frank Allen.

In discussing a matter of this sort it is desirable to know exactly what the problem is, and wherein lies the difficulty which requires a remedy; and it seems to me that the present case may be described something as follows: There is a certain portion of the population residing within half an hour from the door of their residence to the door of their business, and it is my belief that this half hour of travel is not considered burdensome by most people, and we should not be justified in making any very large expenditure to improve their transit facilities. There is another certain portion of the population doing business in the city, but living an hour or more in time from the city, and these people, it seems to me, evidently feel the necessity for rapid transit so little, that we should not be justified in making any very large expenditure to improve their transit facilities. There is, however, another portion of population living in a belt of country between the other two portions, and most of these people may be considered to be just beyond the reach of what may fairly be considered rapid transit, but not so far away but that improved facilities are constantly desired. This intermediate class is a very large one, and it would be profitable to make a considerable effort to accommodate them. Most of the people of this intermediate class are at present served by the horse railways rather than by steam railways, and it is believed that they would be reasonably satisfied if brought within 30 minutes from door to door. It seems to me unwise to have assumed that no substantial relief can be secured from the street railways. It does not follow that a speed of 6 miles per hour is the highest that will ever be allowed in Boston. Cable roads are successfully operated in other cities and seldom at a less speed than 8 miles per hour, while in Chicago certain lines run at 14 miles per

hour, and we have the authority of Mr. Holmes, of the Chicago lines, that in Chicago the cable cars run with far greater freedom from accidents than the horse cars. By the use of cable cars, or perhaps preferably electric motor cars, the speed could be increased sufficiently to extend the 30 minute limit about a mile. In addition to this, in the direction of Roxbury and Dorchester, the West End Railway Company might set aside, say (a) Shawmut avenue, and (b) Harrison avenue and Hampden street, for through travel, making no stop from (a) Eliot street, or (b) Kneeland street, until Dudley street should be reached. By improved methods of operating in this and other ways, the 30 minute limit could be still further extended so as to include most of this intermediate class, while those living within the present 30 minute limit would receive a proportionate benefit.

It seems to me that 30 minutes is a reasonable time to take as a limit within which little dissatisfaction would be felt. I believe that as far out as the Roxbury Post office, the horse-car service is reasonably satisfactory now; and not very many years past, when the greater part of the population lived within a 30 minute limit, little or no complaint was made, and even of late the dissatisfaction has not been marked, except when, through change of management or other cause, the horse-car service has temporarily deteriorated.

Whether 30 minutes or some other number of minutes be the proper figure to use for the purpose, it seems to me that we should look to the improvement of the present street railway lines in the way of increased speed and improved methods of operation, expecting that the situation may be so far relieved that for the present, and for some time to come, there will be no necessity for the extraordinary (though not necessarily unwise) expenditure required for Mr. Manley's scheme.

By Henry Manley.

There seems to be some misapprehension as to the reasons for advocating that trains should run through the city instead of coming to the city and returning. In the first place, it requires a large amount of valuable space in which to accomplish the feat of turning a railroad train, and secondly, much better service can be rendered by not turning. For instance, a train brings in a load of passengers in the morning, distributes them throughout the city, and then instead of returning nearly empty through the city, it rapidly pushes on into the country in the opposite direction from which it came for another load. Each stop is also a departure, and the whole ceremony of backing out of the station, turning the engine and getting it to the other end of the train, backing into the station and waiting to fill up the train, is avoided, or rather is compressed into the one stop, thus annihilating time and space, which I take to be the special mission of rapid transit.

It is not contended that the inhabitants of Dedham have an intense and unsatisfied longing for visiting Chelsea, though, perhaps, it may equal the desire of the denizens of City Point to visit Cambridge, or the people of Mount Pleasant to see the classic precincts of Charlestown Neck or those of Roxbury Crossing to travel to Winthrop Junction. Yet the

West End road finds its reward in providing transportation between the latter places—all for one fare. The point does not lie in traveling as far as the money will carry you, but it enables a resident of any point on each of these long lines to visit any other point, by which arrangement the largest number of people are accommodated, and the coffers of the railway company filled.

The advantages of the system are also shown by applying Mr. Doane's figures to the case. He assumes that 125 trains arrive and leave the Northern stations daily, and an equal number from the Southern stations, making 500 arrivals and departures. Now on the proposed road, with through trains, each arrival is also a departure, which halves the number, and as the stations will be on opposite sides of the road, with no connections between them, this halves the number again, so that if all the trains which now arrive and depart from Boston were to run over the road as proposed, the stops at any particular station would be just 125 per day. This spread over 15 hours gives a train every 7½ minutes. It would be necessary to provide at least three times this number of trains at the opening of the road to sufficiently accommodate the increased travel. The Third avenue elevated road in New York runs 57 trains (round trips) per hour; the Sixth avenue, 50, and the Second, 43, and the reason why they are not run at more frequent intervals still is lack of switching capacity at terminal points. The average stop at stations is 15 seconds.

The Boston & Albany Railroad brings into Boston about 10,000 passengers daily, and takes out an equal number. If from any cause the terminal station could not be used, it would be entirely feasible to receive and deliver all these people at the two small stations at Columbus avenue and Huntington avenue, always provided that trains make only the stops now made at those stations, and use the present yard room for turning.

The amount of land required to connect the Northern and Southern stations would not be large. The distance is about a mile, and a sixty feet wide location is but little more than seven acres to a mile,—less than the area required for a union station for the Northern Railroads.

The argument that business has adjusted itself to the present condition of things is simply a statement that natural inertia is opposed to any change. Business will adjust itself to improved circumstances with the greatest readiness.

The strongest proof that more rapid transit is needed, is given by the universally admitted fact that walking is the quickest way to reach any desired point in the heart of the city. Now, walking is a method of transit which is very old, and there is no record that it has been materially quickened in the last 4,000 years. It is also an excellent mode of exercise, and will still be open to the public when more speedy methods of travel are introduced.

It is not contended that the connecting link will bring this road to every man's door, but it will provide trunk routes in all directions, which by judicious extensions can be made to cover the whole ground in a comprehensive manner.

By Albert H. Howland.

In order to reach a conclusion as to what course is feasible to improve our local passenger transportation, I think a study of the table that I made out (see page 287) will be useful, and as I omitted the reading of the table at the Society meeting, it may not be amiss to point out the bearing of some of its data, for I think it contains in a large degree the gist of the question.

An elevated railroad is very expensive, and requires a dense population to support it, so that there arises the question: How far into the suburbs can such a road be profitably extended? The cost of the New York roads, according to their capitalization, is $1,500,000 per mile, and that I think is without including damages to abutters. But assume that the cost here would be only half that amount, and that no allowance need be made for damages or for draw bridges. Then the interest at six per cent. will be $125 per day; operating expenses will be at least twice as much, so that gross earnings must be $375 per day, and the mile of road must have a patronage of 3,750 passengers at ten cents each per day. Assume that the tributary population must be three times as great and that it occupies the territory for a half mile each side of the road, and deduct 10 per cent for patronage contributed by the rest of the road. With these assumptions and with no allowance for competition by other roads it would seem that it is feasible to extend an elevated road into the suburbs only so far as a tributary population of 10,000 per square mile is assured. Reference to the table shows that the average population per square mile between the 2 and 3-mile limits is 15,000, but is only 3,700 between the 3 and 5-mile, and 1,100 between the 5 and 10-mile limits. Brighton (which is nearly all between the 3 and 5-mile limits), if it had a population of 10,000 per square mile, would have 40,000 inhabitants instead of its 10,000; Dorchester (which is nearly all between the 3 and 6-mile limits) would have 70,000 instead of its 24,000; Newton (which is between the 5 and 10-mile limits) would have 180,000 instead of its 21,000. Between the 2 and 3-mile limits the area is about 10 square miles, already traversed by 9 steam roads (including branches), averaging only about a mile apart. Between the 3 and 5-mile limits the area is 36 square miles, now served by 15 steam roads (including branches), averaging but a little over a mile apart. As regards the territory within the 2-mile limit, it seems likely that the street cars will accommodate most of its population as well as elevated roads would. Those who think that it is practicable for the people within these limits to be provided with a system of elevated roads, should observe that the area to be covered is 53 square miles within the 5-mile limit, whereas in New York it was only 11 square miles, and that the corresponding population is not half as great here as there.

Without considering in detail whether there are not a few *special* localities between, say, the 2 and 5-mile limits that might support elevated roads, it seems to me that my figures show that it is out of the question at present for that territory to be *generally* provided with a system of such roads, and that the general welfare will be best promoted by utilizing the 166 miles of existing roads within the 10-mile limit, with their numerous tracks (constituting a plant that could not be duplicated by

the expenditure of tens of millions of dollars), by first connecting them so that for this purpose they would form a single system, and then improving the accommodations in the suburbs by adding such branches or parallel or loop lines (elevated or otherwise) as business may justify.

If a road has largely extended its terminal accommodations it may thereby be put in a position to secure a greatly increased patronage from the suburbs by a short branch or loop line, while without the terminal improvements such increase would be out of the question. Take, for example, the case of Harvard square and the Fitchburg road. If the road ran to Summer street, then a three quarter mile branch to Harvard square would enable it to carry passengers between those points in 15 minutes; but if, as now is the case, the would-be patron of the steam road has got to make three trips of the journey and pay three fares, he prefers to take the street-car for the whole journey and spend three-quarters of an hour in getting to his destination, and probably he saves time and money by doing so. With the connecting road built probably new stations would be opened within about the 2 mile limit where now they would be useless; the table shows that the stations are as far apart in this, the densely-populated part of the city, as in the sparsely-settled territory between the 5 and 10-mile limits.

As regards travel from one suburb across the city to another, if one could make a six-mile journey, say from Savin Hill to Everett, as quickly as he can go from Boston to Lowell, it might often be convenient: if it could be done in half the time, probably such travel would largely increase. But the accommodation of this inter-suburban travel, instead of being the main object, is of comparatively little importance. The great points to be gained are entirely different. This connecting road will give to the population (present or prospective) of some 200 square miles of territory within ten miles of City Hall as ready access to two or three square miles, as it now has to half a square mile of the busiest part of the city. From the table it will be seen that there are 172 stations between the 3 and 10-mile limits. The building of this connecting link will multiply three or fourfold the territory near the centre of the city that will be readily and conveniently accessible from nearly all of these stations; it will give the passengers from these stations the choice of five or ten times as many points for leaving his train within, say, the 2-mile limit as he has now; it will give the laborers, mechanics, clerks and others a much wider field in which to seek employment without giving up a permanent home in the suburbs or abandoning the hope of having one. If it be assumed that the average suburban resident now walks an equal distance to his suburban station and from the city station, and that the connecting road would transfer half the city walk to the suburbs, then what we might call the habitable suburban territory will be more than doubled at some 150 stations. On the contrary, the building of an elevated road from the South End to Charlestown would accommodate only special localities and would block the way to *general* improvement.

The fear that this connecting road will aggravate the present congestion near the business centre, I think is groundless, except in so far as it

will cause the city to grow by making it a better place to do business in. On the contrary, it will make greater diffusion possible. Business sticks close to the centre now. because, in so far as it goes to one side, it becomes, to a considerable degree. inaccessible to customers from the other side, but a connecting road would make a large central territory equally accessible from both sides.

The scheme that seems to me feasible is that the connecting road be used for only the suburban passenger business; that the other traffic be conducted as at present; that there be built two tracks of elevated road on a tolerably direct route between the northern and southern stations, probably most of the way over the streets, but perhaps partly through the blocks; that sharp curves and steep grades be used, so as to keep down the cost. attain elevation in a short distance and obviate grade crossings; that the road be located with a view to adding two more tracks in the future; that it be owned by the present steam railroad companies and the service be conducted by one management; that there be no central station; that no fragmentary roads of such kind or so located as to conflict with the construction or operation of this road be permitted. If the use of steam on the connecting road be inadmissible, it would be possible to provide special motive power there.

It will be a great waste to the community if a separate system of elevated roads be constructed in the heart of the city in such a way as to prevent our present excellent and enormously costly system of steam roads from being further improved, so as to carry their suburban passengers a mile further into the city without change of cars.

The mile of connecting road is liable to be so very expensive that there is needed for its construction such financial backing as would be given by a combination of the steam railroad companies, and when it is once built, the community should have all the benefit it can be made to yield by its being available to all the roads that can advantageously use it, including even new and independent elevated railroads.

LEGISLATIVE CONTROL OF RAILWAYS.

By Edwin E. Woodman, Secretary Chicago, St. Paul, Minneapolis & Omaha Railway.

[Read before the St. Paul Society, April 1, 1889.]

In a number of our States the Constitution provides that acts of incorporation may be altered or repealed at the pleasure of the Legislature, thus taking those charters from under the rule in the celebrated Dartmouth College case. The efficacy of this reservation of authority by the State was tested and judicially determined in the suit brought by the Attorney-General of Wisconsin against the railroad companies that opposed the regulation of their rates by what was popularly known as the Potter law. The Supreme Court of Wisconsin declared that law constitutional under the reserved power mentioned, and this decision was sustained by the Supreme Court of the United States, notwithstanding the steadfast adherence of that tribunal to the precedent in the Dartmouth College case, abundantly showing that Wisconsin, Iowa, Nebraska

and some other States exercised a wise prevision respecting the growing power of corporations in general as a principal element in the development of State and national wealth, and the corresponding need of their being held in due subordination to law and government.

Nor in States like Minnesota, where this reservation of power is not explicitly set forth in the constitution, have the courts failed to find a ground for legislative control of railway rates, that ground being the doctrine of the inalienable nature of the sovereign powers of a State, such as the police power and eminent domain; that where a franchise to take a toll is granted, it must be considered as being in the hands of the subject, but still belonging to the State and fully under State control; that the right of eminent domain can only be delegated, not alienated, and that corporations exercising it therefore possess a public character, must perform a public function, and in their very nature and origin are subject to the sovereign authority. This reasoning places railway corporations in the same category as municipal corporations, that for ages have been held to a strict accountability to king or commonwealth in the exercise of their franchises, and it removes them from the list of private corporations, that universally have enjoyed a broader liberty than the others. While the control of municipal corporations by the State is an inheritance from the Middle Ages, marking the rise of the people, or the consolidation of political power in kingdoms at the expense of feudal lords and of the independence of isolated towns and cities; and while such subordination is still essential to a due supremacy of the State, to the union of all its parts in a well-balanced and operative whole, the discussions by our judiciary clearly manifest that railway corporations have been forced under the same classification with municipalities, rather than fallen there naturally. The reason is that these influential bodies corporate were not in the imagination, much less in the rational view, of the ancient law-makers; that the rise of their power called for new buttresses and the adaptation of old means to new ends; that hence old names had to be applied to new things, in their nature really nondescript. Thus the same judges who call railway companies public corporations assert the inviolability of the property rights of their stockholders, as if they were strictly private corporations; and the resemblance of these companies to public corporations, as that denomination was understood before the invention of the railway, certainly is less near and obvious than is their likeness to private corporations of unquestioned character, since they are the enterprises of private persons, carried on with private capital and under private management.

These legal grounds of control having been sustained by the Supreme Court of the United States, they have served as the foundation of the restrictive laws that, especially in the Northwestern States, form so considerable a body of ill considered and tentative legislation. But while the legislator must find a constitutional warrant for his laws, the student of social economy will look for a broader basis of support for such control than possibly any constitution will supply, a support in reason and equity, such as distinguishes the long-settled principles of the common law. On such a view, the fact that a railway company possesses the monopoly, not legal and artificial, but circumstantial and

natural, of a great deal of the traffic tributary to it, is the reasonable and equitable ground of public control, the ground on which constitutional and statutory restraints themselves should rest. Could the wealth and power of these companies have been forecast by the great and wise men who erected the safeguards of liberty on this continent, it would not have been necessary for courts of the present day to put strained constructions on constitutional powers, because the control of these corporations would have been directly and explicitly provided for. In that case it would not have become necessary to take the position that the exercise of the right, delegated by the State, to take private land for public use, converts a private corporation into a public corporation. The plain fact is, that no State, any more than an individual, will make large bargains or concessions that are wholly one-sided and benefit only the opposite side. Where States have granted right of way over State lands, or exercised the right of eminent domain on behalf of railways, it has not been done that the whole benefit of the act, or any great part of it, might inure to the small number of persons who owned the charter for the road, not at all. If the building of a railroad create no public benefit, the State, we may be sure, will not advance the project; and notwithstanding the effective use that has been made of the plea that private property has thus been appropriated to public use, by grounding statutory control on that plea, the fact should be remembered that the use is primarily for the public, and not for the stockholder. It is indisputable that no railroad of considerable length could have been built, or can be built, without the exercise of this power on its behalf by the State. If any company had capital enough (as no company ever will have), a road might be built without troubling commissioners or courts with questions relating to right of way. The right of way could all be purchased, if money for the purpose were unlimited. But because private greed is as ravenous a lion as corporate rapacity is, the State compels me to sell the right of way over my land for a reasonable sum, and does it on the ground that I should not be permitted to obstruct the public good by my obstinacy or avarice. In that case the State exercises its right of eminent domain on behalf of the railway company in exchange for the general benefit to the commonwealth, or to the people, that will result from the building of the road. In the words of Chief Justice Marshall: "The objects for which a corporation is created are universally such as the government wishes to promote; they are deemed beneficial to the country and this benefit constitutes the consideration, and in most cases the sole consideration of the grant.' The grant here referred to is the charter or franchise. The exercise of eminent domain is incidental to this, because no railway company could build its road without this assistance from the State. The right to condemn land, therefore, is an essential part of the grant, which grant is the equitable consideration given by the State for the benefits to be derived from the road when it shall be built and put in operation. The right to regulate tolls really rests on another and different consideration, namely, that the State has assisted to erect a monopoly, against which the people have no adequate protection but its sovereign power.

A railway company usually does possess a monopoly of transportation

after its own method, in its own field. As to non-competitive points, or all stations except terminal stations and junction points, the company is securely in possession of a large volume of traffic that is distinctively its own; not because the company's charter confers exclusive privileges, but because the company renders to the public the best and cheapest service, by this means alone superseding other modes of transportation, and even destroying any motive to build a second line of railway close to a first. Such competition as this would afford is usually prevented by the obvious financial folly of such an undertaking on the part of the second company, especially in a country like ours, in which few railways, even among those having favorable circumstances of situation and breadth of field, are profitable ventures. Reference is now made to extended lines of road running through the open country, and not to such exceptional cases as suburban or inter-urban lines, which partake of the character of street railways.

In addition to this freedom of scope over a considerable area, or what we may call the natural monopoly of the line, the further important and analogous fact is to be considered, that railroads lie at the very foundation of society as it is now organized in this country. Notably in the West the rule of development has been, railroads first, then farms, towns, villages and cities. Here the whole social fabric rests on railroad transportation as the fundamental requisite of its existence. The railroad and the settlement are inter-dependent, the one operating as a function of the other, and this mutual relation stimulates the growth of both. If all the railroads of the country were to be destroyed, after the policy of the Chinese in regard to the only railroad they ever had, the decay of the West would not only be inevitable but immediate. Agriculture would at once be destroyed by lack of markets, the ruin of towns and cities would quickly follow, and a reflux of emigration towards the East must of necessity take place. For without railroads, and all that they have done for the development of the West, we should not now be admitting four rich and powerful States to the union, but all the vast territory west of the Mississippi would still be the home of the Indian and the buffalo, with only here and there a small settlement of white men on the banks of its navigable rivers. Railroads so unite distant centres of population that cheap and rapid transportation promotes business activity beyond what mere density of population is observed to do. Railroads are like nerves to the social system, ramifying everywhere and carrying vitality to every centre of industry. The rush of the express train is contagious to the people. Further, the movement of population has largely been controlled by the building of lines of railway, since the hard conditions of life in a new country are very greatly ameliorated by their existence; so that, taking these several considerations into view, railways are subservient not only to the welfare and happiness of the people, but to the very existence of civilization in its present state; and therefore, on rational grounds alone, railway companies should be made subject to such control in the use of their franchises as may be necessary for the protection of the general interest. And here, again, we touch upon the common law, the foundation of all our most valued institutions, in which for more than two centuries past the principle has

obtained that when private property is so used that a public interest attaches to it, as in the case of a monopoly, or of a franchise that practically amounts to a monopoly, it is no longer strictly private property, and the right of the legislature to exercise control over it by statute cannot be questioned. On this broad ground, also, the Supreme Court of the United States has sustained the validity of such legislation.

If there remains with any one a theoretical ground of objection to control, there is no practical ground for its advocate to stand on. The opposite theory has become too thoroughly imbedded in the decisions of our courts to admit of further controversy; and, the ground of discussion having thus been cleared, the question is upon the extent to which this control should go. The legislature of Minnesota has carried this prerogative to the farthest point yet reached, having given to the railroad commissioners of the State unrestricted power to regulate rates. The Supreme Court of the State has decided, not only that the commissioners have unlimited authority to say what rates made by the companies are just and reasonable, but also that any rates made by the commissioners themselves must be deemed to be just and reasonable; that no issue can be raised, or judicial inquiry be had on that question; and has sustained the action of the commissioners in attempting to enforce a rate that on evidence subsequently adduced in a United States Court was conclusively shown to be below the cost of doing the business. So far, then, as Minnesota laws go, as interpreted by Minnesota courts, there is no appeal from the dictates of the commissioners.

To fix a rate that is less than the cost of doing the business has the same effect on the stockholder as to destroy his property. To prevent the property from producing an income, not only, but to burden it with a debt besides, is practically to take the property itself; for the real value of the property is in the productive use of it, and when this quality is taken away there usually is nothing left that is worth having. So the Minnesota law, which has been administered with this effect in at least one case, seems to conflict with the provision existing in both state and national constitutions, that private property shall not be taken for public use without just compensation.

Most of the state laws relating to railway rates provide that they shall be just and reasonable. The railway companies, on the other hand, claim that they want nothing different. The one desire or pretense of honesty may be balanced against the other, but to determine in any given case what rate is just and reasonable is one of the most complicated of economic problems, and very often transcends all power of analysis. There was a great deal of truth and justice in the rule so long practiced by traffic managers, of charging such a rate as the commodity will bear; that is, a rate under which the particular description of commerce continues to thrive, while the railway company is making a profit; and likewise many of the discriminations that until the passage of recent laws were in practice, were based on judicious estimates of the different circumstances and conditions affecting growers, manufacturers, shippers, consumers and carriers. Indeed, the development of the Western States, which is the marvel of our national growth, has in the main been due

to the just and reasonable rates of transportation that the railroad companies, in the years of their liberty, and under the pressure of the natural law of their development, were able or were compelled to dispense to the public; and while they were doing this, they so wonderfully shortened time and compressed space, that the cost of transportation became insignificant in comparison with these benefits. Edward Atkinson states the fact, that a mechanic of Massachusetts, at the cost of one day's wages, can have a year's supply of food for himself moved from Chicago to Boston. Six years ago the writer had occasion to spend some time in the Black Hills. This was long before the advent there of the railroad. But he found that he could replenish his clothing, or supply other personal needs in Deadwood, as cheaply as he had been used to do in Chicago. Yet all these goods had been transported seven hundred miles by railroad, and from the terminus of the railroad had been hauled by oxen two hundred miles farther, and finally had been placed at the altitude of three-quarters of a mile above the sea, without appreciably enhancing their cost to the consumer. What, for instance, would be the necessary addition to the selling price of a felt hat weighing four ounces, if it were carried by rail all the way from New York to San Francisco? The person who will undertake to compute the freight bill on his breakfast will become lost amid decimals too small to express a finite sum of money, and will find that the individual burden of transportation reduces to an absurdity.

The trite saying that a corporation has no soul, is applicable to municipal corporations, and to the State itself, no less than to private corporations. While we are hearing much of public morality and the public conscience, a Legislature will place in three men control over the value, to hundreds of millions of dollars, of the property of private persons scattered all over the United States, a considerable part of these persons being widows and orphans, and will make this control unlimited by depriving the agents directly charged with the administration of these vast property interests of any right to appeal to the courts for protection even against the flagrant injustice of this triumvirate. Tyranny is worse than mere dishonesty, because it includes the smaller vice, and in any State where such a law is retained on the statute book there is, on a mere statement of the fact, a questionable state of public opinion as to right and wrong.

Though legislative control should not be carried to such an exorbitant stretch as this, some correctional supervision of rates by the State will not be contended against, because the State should be the conservator of of all interests, those of corporations as well as those of persons, and because the rate is the essential thing in the public estimation, the point whereto the public interest attaches. How then shall this rate be established, this just and reasonable rate that both law makers and railway managers claim to favor? The question is variously answered by the practice in foreign countries and in our own States. In Belgium and in Prussia state ownership of the lines insures that the government shall make the rate, yet in those countries the people are not satisfied. The government will not operate the roads at a loss any more than private persons are disposed to do it, and, possessing a complete monoply,

is observed to pay small heed to the desires of the public. either by extending facilities or improving the service. The State will not do any unprofitable business, and in order to make a profit reduces the quality of the service, so that inferior accommodations and slower time on the German state lines cost the traveler about the same rates of fare as prevail in England for much greater speed and comfort, and as prevail in this country for greater speed and the best passenger accommodations in the world. In the countries mentioned there now is a public demand for competition by private lines, and so it appears that a satisfactory rate is not to be obtained by entrusting the State with absolute power to make it.

In France government ownership resulted in financial failure, and control is now chiefly through publicity of accounts, with gigantic pooling in some places to regulate rates, and a definite field of territory for each of several great departmental companies. By adopting the Inter-State Commerce Act our people have decided against the pool as a regulator of rates, and so the French system seems to be as little adapted to our present national temper as is the Belgian manner.

In England, where the railway problem has passed through precisely the same stages as it has done in this country, the rate, as well as other matters of joint interest to the public and the companies, is now controlled by the Railway and Canal Commission, a court of record consisting of five members, one of whom must be of experience in the railroad business, another of experience in the law, and the three others judges of a superior court. There is no appeal from this commission on a question of fact, but otherwise an appeal does lie to a superior court of appeal, so that the avenues of justice are not closed to issues of law and equity. Here is an extent of control, reaching to every real grievance, and a form of it, including an appeal to the courts in cases where rights and equities are concerned, that should commend itself to the candid mind. Practically the same system has been in operation in several of our own States, and for useful results has proved the most fruitful of any. For unless railroad commissioners are set up simply for the spoliation of foreign capital, they are powerless to control rates. The best they can do (and it is a sufficient work) is to prevent unjust discriminations, there being, by general admission of persons that have given the subject careful thought, many just discriminations that no public officer should have power to prevent. The railroad commissioners of this country have had no part whatever in the continual decline in rates that has marked the development of railway traffic. Since 1865, the average freight rate on the trunk lines, both east and west of Chicago, has fallen seventy-five per cent., so that the present traffic is done for one-fourth part or less of the rate prevailing in that year. Railroad commissioners have been as powerless to accelerate this decline, as railroad managers have been to retard it. Both have been irresistibly carried along by the strong current of human endeavor, have ridden on the fiercely seething competition in which the railway system of the United States has developed, not as controling it, but as corks ride the whirlpool of Niagara. It is obvious, therefore, that an improper province of State control is the making of rates and supplanting of the traffic manager. And this is

the more certain, if we consider that the making of a rate by the State, that must be accepted by the company as being just and reasonable, logically involves the duty of the State to protect that rate against uncalled-for or unreasonable competition, and drives us towards the French system of securing a definite territory to each line of road, a system that has not secured, to the densely populated country in which it is applied, so good service as is enjoyed on the sparsely settled plains of this country, under the freedom from restraints that has been allowed.

But if the State will insist on giving primary attention to the rate as a rate, in what way will it determine that it is just and reasonable? It is too much to expect that a careful balancing of the many considerations that affect every rate can, in each instance, be undertaken. A decision must be reached on some broad and general grounds, such as that the traffic appears to bear the rate without apparent check to its volume or to its development, on the one side; and on the other side, that the railway company is by such rate enabled to prosper in comparative degree with other business enterprises. And though there is not a strictly logical connection between the cost of a railroad and the rates that it should charge, it may not be too much to ask that a railroad that has been built at a reasonable cost may be permitted to earn a fair profit as compared with the profit in other lines of business. In manufacturing, for instance, the last census shows for the year 1880, that the difference between the value of finished products and the cost of the materials and labor that went into them, was 36 per cent. on the capital invested in the business. If 2 per cent. on the capital be allowed for taxes, 5 per cent. for expenses of administration not covered by returns under the head of wages, and 10 per cent. for renewals of plant, there still remains, as the measure of profit, the amount of 19 per cent. on the capital. Is it, then, too much to ask, that a railway company may be permitted to earn a net income of 6 per cent. on the capital invested in it? He that will not concede so much in the argument is a hard man. Let us see to what conclusion the admission will lead.

In the early days of railroad building in the West the State threw no hindrances in the way, but State, county and city alike fanned the flame of enterprise. The result was that many roads were honestly built at heavy cost, and many more were corruptly built at extravagant cost. A great debt was created in either case. In instances of honest effort struggling with difficulties, in which the new road was not needed, or was in advance of its time, or was not located on a natural line of domestic commerce, bonds had to be sold at enormous discount to pay for construction, and perhaps these bonds have now to be paid at par, after drawing interest on their face value during many years. In cases of dishonest manipulation, over issues of stocks and bonds were resorted to, producing a fatal load of debt. Owing to one or other, or both of these causes, there is among the older roads of the West scarcely one that has not passed through bankruptcy. We have lines now, that after having passed through the hands of a receiver, still show a cost of seventy thousand dollars a mile, though they were built in the cheapest manner, and at present are in poor physical condition. Nor has this evil been confined to the West, nor are modern instances wanting. The West Shore road is perhaps the most conspicuous example of this folly that we have

ever had. Here was a road built at enormous cost to rival one of the oldest and best roads in the country, that had been many years in reaching its own standard of perfection. This West Shore road, on which over a hundred millions had been spent, was bankrupt from the moment of completion. It lost nearly eight million dollars in less than two years of operation, and finally was absorbed at less than half its cost by the road that it was designed either to compete with, or to filch a profit from. Latterly, as a part of the New York Central system, it has been self-sustaining. There are many financial wrecks like the West Shore to point the moral to speculators and teach that an inevitable doom of ruin awaits those who build railroads where they are not needed.

Some of the Western roads mentioned as having passed through bankruptcy in an early day, are now among the greatest railways in the world in extent of line, in wealth, and in useful influence. This is largely due to the economic advantage of consolidating many lines and branches into one great system, but it is principally due to a more conservative, prudent, and, above all, honest administration. Under this reform the financial operations incident to the building of new lines has been revolutionized. For a long time past these extensions have been built for cash out of the treasury and afterwards been bonded for a moderate and reasonable sum, like $15,000 a mile. The old method was to sell bonds at the outset, in order to raise funds for the construction, and to give a share of stock with each bond as a gratuity to the purchaser. Under the latter plan, extensions and branches are added to the main system at strictly cash cost, without adding any fictitious element to the funded debt, without putting any water in it. So general in the early time was the evil of capitalizing roads above their cost, that Mr. Poor estimates that the aggregate reported cost of all the roads in this country is one-half more than their actual cost in money expended.

Now there runs through the reports of railroad commissioners a regret that the actual cost of the roads can not be ascertained; and the declaration is common with them, and with our judges, and with some other oracles of opinion, that the public is quite willing that the companies shall earn a fair profit on the actual value of their properties, such a profit, presumably, as the reader has been asked to concede. Attention is therefore specifically directed to the present worth of one of the railways herein alluded to, as having grown so enormously after its early failure, and the reorganization incident to that failure, and under the improved administration described, namely, the Chicago & Northwestern Railway. An examination of the development of this great system shows a continual decline in the cost per mile of road and equipment during the last ten years, so that, while the mileage is four times what it was ten years ago, the cost per mile is but two-thirds of what it was at that time. The heavy cost per mile of this line at an early period was due to the expense of terminal facilities at Chicago; and though these have been somewhat enlarged, their entire cost is now distributed over a mileage so great as to reduce the average cost of that mileage to an amount that cannot be discredited. It is to be noted in this connection, that the effect of adding to any system a very great mileage of lines economically built, must be to correct by dilution any mistakes made in early days, through which the cost of the property may have

been unduly enhanced, and this corrective will probably grow more effective continually until the errors of the past disappear by attenuation. Substantially the same fact, as to a decline in cost per mile, is true of the Chicago, Milwaukee & St. Paul Railway also; and while the cost of these properties is thus declining, we know that the value of property in general, especially that of lands, is increasing; that the wealth of the Western States is rapidly growing, as shown by assessed and market valuations. Railway property must partake of this increase in value, which is not dependent on cost, but on the development of the country, in which development the railway itself is the principal agent. We have then the Chicago & Northwestern Railway, standing to-day at a cost of less than forty thousand dollars a mile, and able to earn only six per cent. on this cost. It obviously is true, therefore, as a general statement, and having regard to cost of property, and to a fair return on the investment, that the rates charged by this company are on the whole just and reasonable.

But let us look a little further. The cost of the Northwestern road has been distributed over forty years of growth. Much of it dates back to the days of small things, when lands in particular were comparatively very cheap. Take into account its great terminal facilities at Chicago, the extent of its station property in several other large cities and in many towns of importance, together with the present worth of its right of way and station grounds in general, and it will be seen that this road could not be replaced at the present time for anything like so small a sum as the forty thousand dollars a mile that represents its cost. Mr. Jeffery, President of the Illinois Central, recently stated that the new line built by his company, between Chicago and Freeport, cost for construction, without terminal facilities at either end, and without equipment, thirty thousand dollars a mile; and that to produce to-day the terminal facilities in Chicago of the Illinois Central Company would cost from ten to fifteen millions of dollars. Besides these terminal facilities that company owns over seventeen hundred miles of railroad, and its capital stock is thirty-nine millions of dollars, or less than four times the value of the terminal facilities alone. It is also stated that the value of the New York Central terminal facilities in New York, on a fair estimate of their present worth, is equal to the entire outstanding capital stock of that company. The Chicago, Milwaukee & St. Paul Company owns over eleven hundred acres of depot grounds in cities. Fifteen years ago that company had an estimate made by engineers of the cost of reproducing the property at that time, in its then existing condition, and the result was something over thirty-seven thousand dollars a mile. Previous to this, Mr. Mitchell, president of the company, had publicly announced that the entire road had cost thirty-six thousand dollars a mile, and could not be reproduced for a less sum.

It is, therefore, morally certain that the two great rival companies mentioned, the Northwestern and the St. Paul, are not earning a fair return on their cost, much less on their present worth. And what shall be said against their right to earn a fair return on their present worth at any time, on a principle that is universally applied in private business? Such is likely to be the rapid increase in value of these great properties, that if the foregoing principle be admitted, the further concession is compelled, that new and higher rates should be made to yield a fair return

whenever existing rates prove inadequate to do it. This is the logical consequence of admitting the fair principle, that railroads honestly built and honestly managed, are entitled to make an honest profit on an honest investment, the same as is conceded to be the liberty of every individual in his private affairs. It was previously said that there is not a necessary connection between the cost of a road and the rate to be charged. The road may be built where it is not needed, or at an extravagant cost, so that a high rate will be inevitable if the traffic must yield a profit on the cost. Even under these circumstances the service may be the cheapest and the best. But in the case of the roads mentioned, that are fairly worth all they have cost, and that lie at the foundation of an empire of population and of wealth, a fair return on the investment will by every honest mind be conceded to be due the stockholder. There was recently introduced in the Minnesota legislature a proposition to reduce the permissible rate of interest from ten to eight. At once we saw meetings of real estate boards and other business organizations to protest against the measure. At the same time there were also pending in the same body measures to reduce passenger fares and otherwise to diminish the earnings of railroad companies. At the same time, also, the St. Paul Company was finding it difficult to make a half yearly dividend of two per cent. on its preferred capital stock.

Railway rates should not be made directly by statute, nor yet indirectly, through commissioners, but should be left to the free competition among the roads themselves that has worked out the present miracle of cheap transportation. The work of the commission should be confined to the correction of unjust discriminations. But because the charging of exorbitant rates, in order to extort from the public a profit on a foolish or a fraudulent enterprise, is worse than making unjust discriminations, it being the practice of injustice without discrimination, and, therefore, should fall under the police authority of the State; and because, moreover, commissioners and courts so often have stated that a correct estimate of the value of a railroad would materially assist in determining the justness and reasonableness of its rates, it would appear to be an improvement, and desirable, to have a commission that is qualified to deal with this qesution. Let the commission be enlarged, if necessary, and include two or three men of technical education, familiar with railway construction and operation. Then let this commission make its own estimate of the cost and the present worth of the roads. Such a commission would find that the tendency of all the principal roads of the country is to amass property of a value far in excess of their capitalization; that for some roads this condition has already arrived; that it is only the contingency of a short time when it will have ensued with many more; and that if state regulation is not to proceed on an equitable basis, such as will insure to the companies a fair return on the valuation that the State itself may find to be true, and if the State is not willing to protect any rate it may make by preventing the building of unnecessary competing lines, then the honest and prudent alternative is, to leave railway building and rate making to private enterprise, under control of the currents of trade and emigration; for we know that such liberty of action has already given to this country the most extensive, the best and the cheapest railway service in the world.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

APRIL 17, 1889:—A regular meeting was held at the Society's Room, Boston & Albany Railroad Station, Boston, at 19:30 o'clock. President FitzGerald in the chair. Forty-seven Members and eleven visitors present.

The record of the annual meeting was read and approved.

Messrs. William C. Boyce, Edmund Grover, Francis E. Hosmer and Frank B. Rowell were elected Members of the Society.

Mr. Waldo E. Buck, Lake Village, N. H., was proposed for membership by J. R. Freeman and H. B. Wood.

On motion of Mr. Whitney, Mr. Thomas Aspinwall was appointed Auditor for the ensuing year.

The President announced the members of the following committees, selected by the Government in compliance with the vote of Society :

On Weights and Measures—Charles H. Swan, Thomas W. Davis and Arthur W. Hunking.

On the Library—F. W. Hodgdon, S. E. Tinkham, H. D. Woods, C. S. Parsons and E. L. Brown.

The Secretary read a memoir of George A. Parker, an Honorary Member, prepared by the late Samuel M. Felton, also an Honorary Member.

Mr. Albert H. Howland read a memoir of Edward S. Philbrick.

Mr. Lawson B. Bidwell read a paper describing the relocation of a portion of the New York & New England Railroad made necessary by the construction of the Sodom Reservoir of the New Croton Supply. He also gave an interesting account of an embankment built through Whaley Pond.

Mr. Samuel M. Gray, City Engineer of Providence, read a paper giving a history of the various schemes proposed for railroad terminal facilities in Providence.

On motion of Mr. Howe, a vote of thanks was extended to Mr. Gray for his interesting paper.

On motion of Mr. Smith, the Secretary was directed to keep a record book of addresses of such members and others as may report to him that they are seeking employment, giving position desired, addresses of last employer and such other information as may seem desirable.

[*Adjourned.*] S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

APRIL 3, 1889:—305th meeting.—The Club met in the rooms of the Elks' Club, at 8:10 P. M., President Meier in the chair, thirty-three Members and three visitors present. The minutes of the 304th meeting were read and approved. The Executive Committee reported the doings of its sixty-seventh meeting.

The Secretary announced that Messrs. O. E. Hovey and H. Krutzsch had qualified as Members.

Mr. B. F. Crow then read a paper on "Street Car Running Gear." A mode was exhibited and explained in detail. Various forms of construction were described, and the advantages and disadvantages of each explained. Dust was the great enemy of good service. It was a mistake to expect machinery of this kind to run too long without attention. The improvements made in recent years were pointed out. Colonel Meier, Professor Johnson, J. A. Seddon, Mr. Robert Moore, Professor Nipher, Mr. Hubbard and Mr. Taussig took part in the discussion. The advantages of a perfectly clean track were shown, and explanations were given of various devices to accomplish this result. As yet no device had proven sufficiently successful to be generally adopted. Much more power was required to drive a car when the track was dirty.

The advantages and disadvantages of anti-friction rollers were pointed out. Colonel Meier promised the Club a description soon of a new "tractor," in which the whole power delivered to the car was available for traction.

Mr. W. H. Bryan then read a paper entitled "Steam Plants for Electrical Service." The distinctive features of modern practice were explained, and the different factors entering into the problem discused. Comparisons were made between plants arranged with a few large engines, driving counter shafting, from which the dynamos were belted, and the same plant arranged with direct connected engines. In the author's opinion the most important factor in the problem was the amount and hours of loading. The integral parts of a steam plant were discussed from the standpoint of their efficiency in an electrical station. Colonel Meier, Mr. W. Bartlett, Mr. Wheeler, Professor Woods, Professor Gale and Mr. Russell took a part in the discussion. Colonel Meier showed that petroleum fuel was not smokeless unless properly handled. Professor Gale stated that in his opinion a large part of the friction in plants using shafting was due to the friction clutches. If the dynamos were located immediately above the shafts, or not far from there, the dynamos could be thrown out of service without the use of clutches. He also stated that the friction could be reduced by covering the pulleys with paper or leather. This would increase the efficiency of belt contact, and thus enable the belts to be run at less strain, reducing the friction in the journals.

After some informal discussion of meeting places the Club adjourned.

Wm. H. Bryan, Secretary.

April 17, 1889 :—306th Meeting—The Club met at 8:20 P. M., at the Elks' Club, twenty-one Members and two visitors present. Both the President and Vice-President being absent, the meeting was called to order by the Secretary, and Mr. Holman was chosen Chairman *pro tem*. The minutes of the 305th meeting were read and approved. The following applications for membership were announced: Clarence H. Howard, Mechanical Draughtsman, Missouri Pacific Railway, indorsed by L. Bartlett and W. H. Bryan; Pope Yeatman, of the Doe Run Lead Company, indorsed by S. B. Russell and Thomas B. McMath. The Secretary announced that A. L. Johnson had qualified as a Member.

The receipt of several valuable publications for the library were acknowledged. The Chairman announced the death of Col. Henry C. Moore, one of the oldest Members, and a former President of the Club. He also announced that President Meier had volunteered to prepare a memoir, which he expected to be able to present at the next regular meeting.

Prof. Charles C. Brown's paper on "The Sanitary Condition of the Water Supply of New York City," was then read by Professor Wheeler. Professor Brown, being engineer for the New York State Board of Health, had devoted considerable time and study to the subject. The paper presented a vast amount of data, extending over a series of years, beginning with 1872, showing the results of chemical examinations of Croton water. He also gave a statement of the flow of the Croton River for each year, beginning with 1870, together with the rain fall

over the water shed, and the flow of river in percentage of rain-fall. He discussed the water under the following heads: Total solids, hardness, albumenoid ammonia, chlorine and combined nitrogen. His conclusion was that the case for or against the Croton water, as shown by chemical analysis, had not been proven. He gave the results of a personal examination of the water shed, together with suggestions for treatment of several cases of pollution. He also submitted a copy of the series of rules adopted for the sanitary protection of the Croton River and its tributaries. Messrs. Holman, Bryan, Wheeler, Thacher, Ferguson and Bouton took part in the discussion. Mr. Wheeler stated that there was usually considerable newspaper talk every fall about impurities of the water, but repeated and careful chemical analyses had shown it to be harmless. Mr. Bouton thought that the marginal zones along the streams were hardly sufficiently wide.

The Secretary then read a paper by Mr. A. J. Frith, describing a system of marking patterns. The question was treated in detail, and the desirable points explained. A sample record sheet was submitted. Mr. Frith also submitted a brief discussion of economy of manufacture as viewed in the pattern. This question he discussed under the following heads: Economy in the pattern itself; the number and nature of the castings; the subsequent handling of the castings; the object being the minimum cost of the finished product. In the discussion, Mr. Crow spoke of the difficulty of marking small patterns, and also explained the system in use at the Brownell-Wight car shops. Each pattern bore the number of the shop order, and also all patterns used on each order were numbered consecutively.

[*Adjourned.*] WILLIAM H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

APRIL 3, 1889: —The 275th meeting was held at Weber's Restaurant, No. 66 Washington street, at 5 P. M. President E. L. Corthell in the chair. There were about 30 Members present.

The minutes of the last meeting were read and approved.

Resignations were received from Mr. Otto Luhring, Berlin; Mr. A. W. Sullivan, Chicago: Mr. Geo. F. Kirby, Marshalltown, Ia.: and Prof. J. A. L. Waddell, Kansas City.

Applications for membership were placed on file from Mr. James D. McKee, Gross Park, Cook County, Ill.; Mr. Otto Engle, Chicago, and Mr. Benj. Hyde, Chicago.

Upon ballot, Mr. John Sylvester Glenn, Chicago, was elected a Member of the Society.

Some communications were read by the Secretary, among them one from a Member who had unavoidably been compelled to withdraw from the Society for a time, asking what course to pursue to be reinstated. Attention was called to the By-laws which in such a case permitted reinstatement upon payment of current year's dues. A communication was also read from the St. Paul Society on transfer of membership between the various Societies. Mr. Strobel moved that the matter be laid over until a future meeting. Carried.

Mr. Gottlieb, as one of the Committee to secure permanent quarters, made a brief statement to the effect that after a proper search the Committee had found and secured rooms, which, in their opinion, were highly desirable, and that they were in a position to say that arrangements would be effected to keep the rooms open during business hours with an attendant constantly on hand. He hoped all the Members, resident and non-resident, would make a special effort to use their head quarters at every opportunity.

Mr. John Lundie, Chairman of the Committee on Permanent Quarters, having arrived, he read the report, which was duly received:

REPORT.

To the Members of the Western Society of Engineers:

The undersigned, appointed at the last meeting to secure quarters for the Society, respectfully submit the following report:

After a thorough examination of a large number of available rooms which might have been suitable for Society purposes, your Committee secured quarters from Mr. Blair, of the Merchants' Bank, at No. 78 La Salle street, under a three years' lease at $15 per month. An additional cost of about $10 per month will be involved for janitor service.

The Committee suggests that said quarters be the nominal office of the Secretary. All communications pertaining to Society matters to be addressed to and sent out from the above address.

Appended is a sketch of the rooms, which will be remodelled slightly to suit the convenience of the Society. Respectfully submitted,

John Lundie.
Chas. FitzSimons.
A. Gottlieb.

There being considerable business remaining to be transacted, Mr. Herr moved to proceed to lunch before further business. The motion was seconded and carried.

At the conclusion of lunch the President called for discussion on the Report of the Committee on Permanent Quarters.

Mr. Lundie stated that the rooms would be ready by April 25.

In reply to a question, the President announced that the Committee would consider themselves still in office to assist in moving, arranging and advising.

The President called for Report of Committee, created by Mr. Lundie's motion of March 6, to examine into condition of Society with relation to increase of dues, etc.

Mr. Lundie, Chairman of Committee, before reading the following report, said that the report he had already presented might be regarded as a preface to the one now in hand:

REPORT.

To the Members of the Western Society of Engineers :

The undersigned, appointed at the last meeting to report on the whole financial condition of the Society, respectfully submit the following report :

From the Treasurer's report for the year 1888, it appears that the expenses for that year were $1,302.92, and, unless some radical change be made, it is fair to assume that the expenses for the present year, exclusive of additional expense for quarters, will be about the same, say $1,300, provided no retrenchment is made in current expenditure.

The Society, however, has already decided to occupy more comfortable quarters which will involve an additional expense of $500, when annual expenses, exclusive of any outlay for fitting up new rooms, will be about $1,800.

The revenue for 1888 was $1,420.74, and we assume that our present revenue is about the same, say $1,400.

In order to meet the difference between $1,800 expenses and $1,400 income, either the latter must be increased, or the former decreased that amount.

This may be accomplished in four ways, viz.:

1st. By voluntary subscription toward deficit.
2d. By increase of the present average of dues.
3d. By obtaining an increased membership.
4th. By decrease in certain expenses.

If additional revenue cannot be secured there must be a decrease in expenses, and bearing on this subject the Committee begs to direct the attention of the Society to the items of expense involved in the publication of proceedings and of the Journal. The combined cost of proceedings and Journal last year aggregated $626.55. The Committee is of opinion that the proceedings and the papers of the Society could be printed monthly at an expense of about $300 per year.

This would save about $325 annually, leaving a deficit of only $75. An addition of ten new members would cover this amount.

This is the only item apparently where any saving could be made.

To obtain a sufficient increase of income by one of the plans alluded to would require, under the first a pledge from probably forty members of from five to twenty dollars each, under the second an average increase of about one-third of the present rate of annual dues, and under the third an immediate accession of eighty members. It is possible that the first and third might be combined.

Respectfully submitted,

John Lundie,
C. L. Strobel,
L. P. Morehouse.

Messrs. Strobel and Morehouse explained the report as not recommending any action, but simply pointing out directions in which reduction of expenses might be effected.

Mr. Williams moved that report of Committee be accepted, which was received.

The Secretary stated that the motion was pending for the amendment to the By-laws in relation to increasing the annual dues of resident members to $10.

Mr. Williams explained the advantages present and prospective of the Association of Engineering Societies, and the work it was proposed to undertake, and suggested that giving up the JOURNAL meant withdrawing from the Association. He also stated that the cost of the Society's publications had never amounted to less than what was now paid for the JOURNAL, and that by a little effort of the present members, in view of the new quarters, accessibility of library and general advantages now offered, a large accretion to the membership could be assured which, with the proposed small increase in resident dues, would amply cover expenses.

Messrs. Alvord and Nagle coincided with Mr. Williams.

Messrs. Liljencrantz and Rossiter suggested inviting the architects to use the Society's rooms and thus share the expense, but Mr. Gottlieb, the Secretary, and Mr. Morehouse believed the suggestion would be over burdened with inconvenience and undesirable.

The President called the meeting to the question.

Mr. Lundie drew attention to the cost of the JOURNAL, and did not see that declining to subscribe for the JOURNAL carried with it the withdrawal from the Association, but Mr. Williams pointed out that it was practically doing so, as the Association was formed for the purpose of a joint publication.

The President spoke in favor of the JOURNAL as a valuable periodical.

The question of raising the annual dues of resident members to ten dollars was put and carried.

The President called attention to a matter that remained to be considered: that of providing professional entertainment at its regular meetings.

Mr. Gottlieb deprecated the condition of affairs which left so much routine work to the regular meetings and suggested that the Society organization should comprise a Board of Directors who should be empowered to transact all the routine work and leave the meeting to consider engineering questions and important business. He also suggested a method of work.

Mr. Morehouse cordially indorsed Mr. Gottlieb's view and advised the formation of a Board and that the Society should give it their confidence in the transaction of purely business matters.

Mr. Williams concurred and moved that a committee of three be appointed to propose such amendments to Constitution and By-laws as would effect the objects suggested; a slight amendment to increase powers of Committee was proposed by the Secretary and accepted.

Moved that a committee of three be appointed to propose such amendments to Constitution and By-laws as will simplify the methods of transacting the business of the Society. Seconded and carried.

The President appointed the following: Messrs. Morehouse, Gottlieb, Williams and the Secretary *ex-officio*.

The President moved that the following be sent to Mr. D. C. Cregier:

WHEREAS, Mr. D. C. Cregier, an honored member and past President of the Society, has been elected Mayor of this city, therefore be it *Resolved*, That we extend our congratulations to Mr. Cregier, and that our Secretary be instructed to convey the same to him.

This motion was carried unanimously.

It was moved and carried that the next supper be held the first Tuesday in June

After some further talk on moving quarters and purchase of necessary supplies, etc., the very interesting meeting adjourned to meet in the permanent quarters the first Tuesday in May. JOHN W. WESTON, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

APRIL 9, 1889:—In the absence of the President and Vice-President, Mr. W. H. Searles was called to the chair. Sixteen Members were present when the Club was called to order, as follows: Messrs. John Whitelaw, W. H. Searles, James Ritchie, August Mordecai, C. G. Force, N. P. Bowler, C. H. Strong, Ambrose Swasey, E. W. Morley, S. J. Baker, Cady Staley, C. P. Leland, J. L. Gobeille, J. L. Culley, A. H. Porter and Mr. N. B. Wood arrived during the evening.

The minutes of the last meeting were read by the Secretary and approved. The Secretary read the report of meeting of the Executive Board.

The chairman then read the names of five applicants for membership, as follows: A. P. Ruggles, F. P. Gribbon, J. E. Pettee, J. B. Yates, Paul Bickel. These applications have all been passed upon by the Executive Board. The applicants are now candidates for membership and the names will be acted upon at the next meeting. Each gentleman gives a full account of his experience. All are employed by the C. & M. V. Railway, and are recommended by H. C. Thompson and James Ritchie.

Mr. C. P. Force read the report of the Programme Committee for the year 1889-90. On motion of Mr. Gobeille the report was accepted.

Mr. Searles: There is a movement on foot to amend slightly the constitution of the associated societies. My vote on the Board of Membership is required, and I would like to be governed by the sense of this meeting. The Secretary read a letter from Mr. Benezette Williams to Mr. Searles on this subject, also a report of a meeting of the Engineers Club of St. Louis.

Mr. Searles: The question is on the amendment of the constitution of the Association of Engineering Societies; at present the Board of Managers simply has duties connected with the JOURNAL; it is proposed to add to these duties correspondence of any kind that may arise.

Mr. Leland: I move that the matter be referred to Mr. Searles with power to act. Seconded by Mr. Gobeille.

Mr. Searles: Is the Club disposed to go into correspondence with the various clubs with which we are already connected through the JOURNAL? If so, this amendment will empower the chairman of the Board to conduct such correspondence and report resolutions. Each club is and will be independent, but, at present, we have no precise methods of correspondence. The idea is that we may through the association carry on a correspondence: if the club does not wish to enter into an arrangement of this kind I would better vote "no" on it.

An amendment was offered and seconded that the matter be referred to the Executive Board. Mr. Leland withdrew the original motion. The motion that the matter be referred to the Executive Board was carried.

Mr. Leland read the report of the Committee on Banquet. On motion of Mr. J. L. Culley the report was received.

Mr. Bowler moved that the deficiency paid by the Committee be paid by the treasury of the Club—motion seconded. Messrs. Leland and Whitelaw objected and Mr. Bowler withdrew his motion.

The Club then listened to the address of Prof. Cady Staley on Some Experiments with Flushing Tanks.

In compiling details for a system of sewerage I found that each inventor claimed to have the best tank in existence. In order to test the matter I put an

advertisement in several engineering papers that I would receive and report upon tanks. I will give you the records of my experiments upon a few of the leading tanks.

You may say that that the necessity for certainty of action is self-evident, yet I found that the majority of the tanks would not work at all.

The next essential is rapidity of discharge; add to that simplicity, durability and economy of construction.

I examined various tilting tanks, valve tanks, where the discharge is brought about by opening a valve, and siphon tanks. (Makes diagram of a cross-section of a siphon tank and describes it.)

All of these tanks will work with a large amount of water thrown in. In the flush tank the conditions are that the water runs in slowly with just a slight stream. Very few people will wait while that trickling stream starts the siphon. What is needed in a flush tank is a stream that will only fill the siphon once in 24 hours, the question is to stop it. (Makes and explains a diagram.) That particular siphon is sold for flush tanks all over the country. That siphon was sent where we were making our tests. To prepare for the tests we had a large tank holding eight gallons. We tried in vain to make it work, and I finally sent for the manufacturer to send us some one who could work it. I had two engineers and two men at work for three days, and that apparatus would not go. The proprietor tried it for a day, and said, "It must work. I have sold ten since I started from New York." It is not possible to make it work with a small stream.

We got a sort of fever in carrying on these experiments, and many people began to design tanks. A brother of George Westinghouse made a siphon tank. It was ingenious, but too complicated; a flush tank should be so contrived that it may be set to work and never looked at again.

Prof. J. S. Langdon invented a flush tank which works beautifully, but it necessitates a very delicate joint, so while it worked well when a very nice mechanic put it up, it was of no use for ordinary purposes. (Makes diagram of Professor Langdon's tank.)

The Fields tank is one of the best. (Makes diagram of the Fields tank.)

In the course of my investigations, I found on many sewers a growth of fungus; a considerable part of the organic matter was received from the house sewage, so you can see what a manufactory it is for sewer gas. Flush tanks, in connection with houses, would flush the sewer out and ventilate it.

The Field tank is one of the good tanks, and yet, in the last number of *Engineering News*, a correspondent from Memphis says it does not work satisfactorily there. It works nicely if it is properly started and the water is clear, but if the water is filled with sediment it will absolutely refuse to work. (Makes diagram of the Rosewater tank and describes it.)

There is only one difficulty with the Rosewater tank: there is a small jet of water, and if there is much sediment it will stop right in the cock. If you have clean water this tank will work nicely.

I suppose there were twenty-five men experimenting on this in Schenectady; among others was Professor Chaplin, Professor of Civil Engineering at Harvard College. I met him one day and he said: "I am on top now; I have this siphon tank." The next time I met him he was not so elated, he said: "The siphon is on top, but there are more things in siphons than are dreamed of in your philosophy." The siphon is still on top.

The Van Vranken flush tank is made in this way. (Makes and describes diagram.)

Van Vranken tanks have been running satisfactorily for three years.

Of the valve tanks the best is Pierson's. (Makes and describes diagram of the Pierson tank.) This tank works well, except where there is sediment in the water.

There are other ways of flushing sewers. One used sometimes on the continent is a large tank on wheels which is drawn up to the end of the sewer and the water discharged. Sometimes a pipe is connected from the water-works, and there are other methods, but the flush tank has the advantage of being automatic; it takes care of itself.

Mr. Whitelaw: I think the plan of flushing from barrels is used in Chicago a great deal.

Mr. Mordecai: Is it not very expensive?

Mr. Force: It is used only where really necessary.

Mr. Whitelaw: I understand that the portable tank system is used in Chicago because the sewers are so shallow that stationary tanks cannot be placed so as to act satisfactorily.

Professor Staley: I think flush tanks should be placed in every house. The vilest part of every system of sewerage is the sewer leading from the house. Now small flush tanks in the houses will insure a clean sewer.

Mr. Force: The sewers in Chicago have a very slight grade. One reason why they prefer the portable tank system for cleaning sewers is that they only flush those that require it. I suppose most of the members here know that it is not a practice to flush sewers in Cleveland. We have so much grade that the street sewers are rarely flushedr they are self cleaning. We have in some places a very black mud, or clay, that oozes through the joints of the brick and makes it difficult to keep the sewers clean. A few small sewers are regularly flushed by using the hydrant and hose.

A Voice: What is the largest tank in use?

Professor Staley: The largest I know is the Vibbert tank in Kalamazoo—it is a 7,000-gallon one.

A Voice: Is it necessary to flush the large sewers if you flush the pipes in the house?

Professor Staley: If you flush all the small pipes you get a combined flow sufficient to flush the large ones.

Mr. Mordecai: How long would it take?

Professor Staley: You can empty a 200-gallon tank in about half a minute.

Mr. Culley: Where are these tanks located?

Professor Staley: Under the grade of the street.

Mr. Baker: Are they filled by the surface water?

Professor Staley: No, from the water-works.

Mr. Baker: How often should they be emptied?

Professor Staley: Every 24 hours—200 gallons in 24 hours. You can stop it off entirely if you wish.

Mr. Porter: Is not this flushing in use in those cities where the roof water is not allowed to flow into the sewers? I believe that is the case in Memphis.

Professor Staley: It is the case there.

Mr. Porter: The surface water, that from the roofs, etc., furnishes a pretty fair flush here.

Mr. Searles: There are strong advocates for the separate as well as for the combined sewerage system. From what the professor has said this evening it would seem desirable that the street water should enter the sewer. It has been objected that the stream of water going in would require so much larger sewer.

Mr. Whitelaw: I think some of the sewers in Cleveland have been worn by the action of sand or grit.

Mr. Bowler: There are sewers in the city where there is no paving on the streets, and they get the washing of the soil.

Mr. Force: I think most of our sewers are paved with Medina stone. I have taken up sewers where the bricks were much worn. The length of time it takes to wear out a sewer varies with the grade, etc.

Mr. Whitelaw: The accident on the sewer in Pearl street running into Walworth Run was owing to the wearing out of the bottom of the sewer.

Mr. Mordecai: According to the records, how long can cast iron water pipe remain under ground in a condition to convey water?

Mr. Whitelaw: I do not think that the life of cast iron water pipe has been determined yet. At the Centennial Exposition I saw water pipe that had been in use 69 years. The supposition is that if rust has penetrated a certain depth it forms a protection to what remains, and after that the pipe is practically indestructible.

Mr. Force: I once heard some water-works engineers give their experience in that line. One point was that the pipe lasts different lengths of time in different soils. Some soils corrode the pipe very rapidly.

Mr. Whitelaw: That is true of any soil containing acid. The worst soil I know here is where there has been cinder filling. I know one line of pipe that is honeycombed. We have found spots where the iron was like plumbago.

Mr. Porter: I understand Professor Staley that he recommends a flush tank in every house for the purpose of cleaning the sewer and purifying the air in the house drain; what size should the tank be?

Professor Staley: From 20 to 30 gallons.

A Voice: What system is in use in Memphis?

Professor Staley: It is a special system—Colonel Waring's.

Mr. Bowler: In regard to the house system of flushing, I think it is practical and very important. Would not a very large supply of water be required to flush all the house sewers?

Professor Staley: I think Mr. Whitelaw will bear me out in the assertion that the water that is wasted would flush all the sewers in Cleveland.

Mr. Whitelaw: One-twentieth of the water wasted in Cleveland would flush every sewer.

Mr. Porter: The outlet should not be less than 4 inches in diameter.

Professor Staley: I would not put the flush tank on the water-closet, you understand, I would put it on the large soil pipe.

Mr. Mordecai: I would like to ask Mr. Whitelaw whether he thinks it necessary to take into consideration the deterioration of iron pipe in ordinary soil.

Mr. Whitelaw: For small culverts I would say use cast iron pipe; it is used now very extensively for railroad culverts. In general I would not consider it necessary to take the nature of the soil into consideration.

Professor Staley: On the Hudson River, where some boilers went to pieces rapidly, it was found that there was sulphur in the water.

Mr. Mordecai: The culverts to which I have reference are in the neighborhood of a coal bank.

Mr. Whitelaw: That would be objectionable.

Professor Morley: Some soils contain acid that would be rapidly fatal, but they are rare. There are places where acres and acres bear scanty vegetation; and our geological survey established the fact that the soil was acid. A rapid corrosion of iron pipe is to be attributed usually to local conditions. Water containing sulphuretted hydrogen would corrode pipe rapidly. The sulphuric acid of soils containing iron pyrites would also produce rapid corrosion. Water that comes through a mine is also sometimes fatal to iron pipe. It would be well to have some of the water filtered, put in a small vial and allowed to evaporate to a tenth or twentieth, then have some very delicate litmus paper placed in it: if the paper is in the slightest degree reddened you can detect the presence of acid. Sometimes the debris of manufactories causes corrosion of a pipe.

Mr. Whitelaw: A friend of mine in the city has a large condensing engine in his manufactory drawing water from the river. He had a new pipe to supply his condenser. It was not in use more than two years when it leaked; it was renewed and soon leaked again. My advice was asked, and I found that the pipe was

located under the coal bin. I suggested that the pipe was corroded by acid from the coal, and as the coal could not be moved, I suggested the substitution of cast for wrought iron; it could be renewed, and would probably last longer. That was twelve years ago, and the cast-iron pipe is still in use. Acid acts more slowly on cast than on wrought iron.

Before adjournment, it was announced that the President was in California, but would return in the course of a week.

The members expressed a hope that Professor Staley would propare a paper on the separate and combined systems of sewerage.

[*Adjourned.*] JAMES RITCHIE, Secretary.

CIVIL ENGINEERS' SOCIETY OF ST. PAUL.

APRIL 1, 1889:—The regular meeting was held in the Hotel Ryan, President Loweth in the chair. Twelve Members present.

The minutes of the last meeting having been read and approved, the application of Mr. Karl Lehman for Membership was voted upon and he was elected.

Upon motion of Mr. Curtis a Committee to report upon the advisability of a Standing Committee upon Membership was appointed by the chair, consisting of Messrs. Morris, Curtis and Davenport.

Upon motion of Mr. Estabrook, it was resolved to donate complete bound copies of the JOURNAL OF THE ASSOCIATION to the Minnesota Historical Society.

The paper of the evening was a carefully prepared article by Mr. E. E. Woodman upon "The Legislative Control of Railways."

After a short discussion of some points in the paper by Messrs. Horton, Curtis, Mason and Loweth, and extending to Mr. Woodman the thanks of the Society for his valuable monograph, the meeting adjourned.

GEO. L. WILSON, Secretary.

ENGINEERS' CLUB OF KANSAS CITY,

APRIL 1, 1889:—A regular meeting was held in the Club Room, 200 Baird Building. President O. B. Gunn in the chair.

There were present sixteen Members and four visitors.

Minutes of the last regular meeting and that of the Executive Committee were read and approved.

On canvass of ballots R. L. McAlpine was declared elected as Associate Member.

Letters from the local societies of Montana, St. Paul and Minneapolis with reference to Transfer of Members were read. In general action was deemed desirable, but the prevailing opinion was that the matter should be referred to the Board of Managers of the Association.

A letter from Mr. Sonne, offering to resign from the Committee on Transfer of Members on account of absence from the city, was read, but the sense of the meeting was that he should remain on said Committee.

The paper of the previous meeting was discussed by Messrs. Goldmark and Breithaupt. The latter stated the approximate cost of the bridge repairs described as one cent per pound.

A paper was read by Mr. Kenneth Allen on "Pollution, with Special Reference to Water Supply and Sewerage." Organic impurities were especially referred to; their detection by chemical and biological analysis; the character and action of bacteria briefly described; and the allowable limits of impurities mentioned.

After discussion by Messrs. Breithaupt, DeCourcy and Elliott, the President introduced Dr. F. B. Tiffany as a pupil of Dr. Koch, of Berlin. Dr. Tiffany

exhibited specimens of Anthrax Bacilli, infusoria from hay infusion, water from O. K. Creek sewer, and other specimens under microscopes magnifying 400 and 800 diameters.

Dr. Tiffany was tendered a vote of thanks.

Mr. Robert A. Crawford was proposed as Associate Member by F. W. Tuttle and H. H. Filley.

[*Adjourned*] KENNETH ALLEN, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

MARCH 16, 1889:—The regular monthly meeting was held at the office of Mr. E. H. Beckler, at 8 P. M.; President B. H. Greene in the chair. There were present Messrs. Foss, Wheeler, Sizer, Haire, Ross, Danse, Ellison, Walker, Keerl, and Mr. O. C. Dallas as visitor.

Mr. Foss, Chairman of the Committee on Highway Bridges, read the Committee's report upon the communication of January 18, 1889, from the Engineers' Club of Kansas City, inclosing the bill prepared and presented to the Legislature of Missouri embodying provisions for securing reform in the planning and construction of highway bridges. The "Substitute" for said bill, recently received, was read.

The Committee's report is as follows:

"We have examined the proposed act, and consider it a good law, but think that Montana is too new a country to pass such a law at the present time. We would. therefore, recommend that the Secretary be instructed to write to the Kansas City Club and state that while the Society is in full sympathy with them in their movement to secure the needed reform, they are doubtful of the expediency of attempting to secure any legislation on the subject at the present time in this Territory, that their bill will be kept for future reference, and to ask them to inform us with what success it meets in their State if it becomes a law."

The report was approved and its recommendations ordered to be carried out.

In the absence of the Committee to whom had been referred the communication from the Engineers' Club of Kansas City relative to entering an alliance of engineering societies for the transfer of Members, the Secretary stated the substance of the communication and reported having received since the last meeting a communication upon this subject from the Civil Engineers' Society of St. Paul, inclosing a copy of their Committee's report. The question was discussed and resulted in the Secretary being instructed to express to the Engineers' Club of Kansas City the hearty co-operation which this Society feels disposed to accord to the movement, and to state that the details of the scheme would be left to the determination of the Board of Managers of the Association of Engineering Societies.

Mr. Ellison, of the Committee on Library and Permanent Quarters, submitted and read the Committee's report, which recommended the purchase of a book-case and an appropriation of $60 to be applied to the purchase of books, to be determined by a committee of four composed of members representing civil, mining and mechanical engineering and architecture respectively.

The recommendations of the report were discussed and action deferred until the next meeting to enable the full committee to report.

Mr. Foss, Chairman of the Committee that presented to the Legislature the Bill "relating to town and village sites and plats," being C. B. No. 36, also the Bill "relating to the location and recording of mining claims," being H. B. No. 34, reported the former as having been signed by the Governor, and the failure of the latter in the Council by a tie vote. The Committee was instructed to secure a copy of H. B. No. 34 as it passed the House, and to file it with the Secretary.

The Secretary submitted the bids received for printing 100 copies of a list of Members, and was instructed to have the work done by the lowest local bidder.

President Greene offered to contribute to the Society's library his *Transactions of the American Society of Civil Engineers*, Mr. L. O. Danse contributed the *Proceedings of the Engineers' Society of Western Pennsylvania*, Mr. F. A. Ross contributed the *Engineering and Mining Journal*, also the *Electrician* and the *Western Electrician.* The contributions were received, and a vote of thanks tendered the contributors.

The Secretary submitted a circular describing "An Index to Engineering Periodicals," published by Francis E. Galloupe, M.E., and recommended its purchase for the library. The advisability of securing said *Index* was referred to the Committee on Library.

The Secretary reported that Mr. A. B. Knight, of Butte, had written the Committee on Topics that he would endeavor to present his paper upon the "Law of the Apex" at the meeting to be held April 20, next.

[*Adjourned.*] J. S. KEERL, Secretary.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

CABLE CONDUIT YOKES: THEIR STRENGTH AND DESIGN.

BY J. B. JOHNSON, MEMBER ENGINEERS' CLUB OF ST. LOUIS.

[Read February 6, 1889.]

The object of a cable conduit yoke is to hold the bearing and slot rails of a cable road in position, and to resist the action of all external forces tending to close the slot opening. They are usually set in concrete, which extends along the sides of the conduit, from yoke to yoke, thus forming a continuous tunnel for the cable. That this opening may be large enough to carry the sheaves, to allow a man to crawl through and to prevent clogging from débris, it is customary to make it about 18 inches wide at the middle and some 36 inches deep below the slot rails.

Since the slot opening should never be over ¾ inch wide, and to pass the grip bar must be at least ½ inch wide, a variation of over ¼ inch in the width of this opening is objectionable. It is not uncommon in St. Louis to find the opening as much as 1¼ inches, and recently a suit for damages resulted from an opening of 1½ inches, thus letting a carriage wheel into it, breaking the carriage and injuring the occupant.

It is also not very uncommon to hear of yokes breaking, especially in the Northern cities.

It is necessary, therefore, that the yoke should be both strong and rigid, the latter quality being far the more important.

I have tested over twenty-five yokes of different patterns at the Washington University Testing Laboratory, the results of which are so instructive that I take this opportunity of putting them on record.

In all the yokes shown on the accompanying plate, the spaces marked *o* are openings. They are all of cast iron, cast in one piece, while yoke No. 4 is cast with a solid web.

Yoke No. 1 (Fig. 1) is a pattern much used in Kansas City, and to some extent in St. Louis. Its weight is 320 pounds, strength 6,000 pounds, and the slot closes about half an inch at 5,000 pounds. It breaks, as shown in Fig. 1, either at *P P* or at *L L*. It is both very weak and very flexible.

Yoke No. 2 (Fig. 2) is used on the Olive street line in St. Louis. Its weight is about 420 pounds; strength 9,000 pounds, with a slot closure of

0.6 inch at 5,000 pounds and 1.2 inches at 9,000 pounds. It is 50 per cent. stronger than No. 1 and about as flexible. This yoke was tested by applying the load directly to the slot jaws, as shown by the arrows, Fig. 2, while No. 1 was tested by applying the load at the outer upper corners. This gave also a leverage some 4 inches greater. It broke either at *B B B*, or at *S S S*, Fig. 2.

Yoke No. 3 (Fig. 3) is used in Denver, and Kansas City, and on the new Olive street extension, St. Louis. It weighs about 360 pounds. It failed at first at *C C C*, Fig. 3, but this opening was reinforced by an inner flange about it, when it failed at *H H*, and *D D*. Several yokes of this pattern also failed by cracking at *A*, the lower side of the upper web section, at bottom. A small web connection across this bottom opening, at *A*, greatly stiffened this yoke and nearly doubled its strength. Nine yokes were broken from this general pattern and weight, but with various minor changes in web and flanges. Their strength varied from 8,300 to 17,600 pounds, the latter result being obtained after the two bottom webs

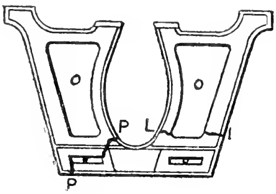

Fig. 1.

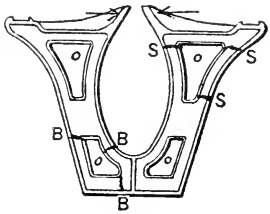

Fig. 2.

were joined, as shown by dotted lines, Fig. 3, and breaking at *D D*. The slot closure of this last form was $\frac{7}{8}$ inch on total load, and $\frac{1}{2}$ inch at 11,000 pounds.

Yoke No. 4 (Fig. 4) is a solid web yoke of the same general pattern as Fig. 3. When its weight is 425 pounds its strength is 40,200 pounds, and its slot closure is 0.77 inch at rupture, 0.20 inch at 12,000 pounds, and $\frac{1}{2}$ inch at 30,000 pounds. It breaks in the line *K K*, Fig. 4. When its weight is 350 pounds its strength is 28,000 pounds, its slot closure is 0.77 inch at rupture and 0.28 inch at 12,000 pounds, the strength of the iron being 20,000 pounds per square inch. This yoke has never been used, but its remarkable strength and more especially its stiffness, strongly recommend it. Its cost is no more than other forms of yokes.*

STRESSES IN A YOKE.

When a conduit yoke is acted on by external forces tending to close the slot opening, it becomes a beam, and for purposes of analysis may be considered as such. Whenever a beam is subjected to bending stress, we have not only direct tension and compression in the extreme fibres, but these are always necessarily accompanied by shearing stresses in the web. These shearing stresses are the greatest along the neutral axis of the beam, and increase usually from the centre towards the ends. The

* This yoke is patented and the patent controlled by the Mullins Silicated Iron and Steel Company, St. Louis, Mo.

maximum shearing stresses, therefore, are found at the extremities of a beam, and they act, not only transversely, but also longitudinally, and are greatest along the neutral axis at the ends.

In all patterns of conduit yokes now in use, so far as the writer is aware, there are large openings in the web of the yoke, as shown in Figs. 1, 2 and 3. Furthermore, the connections between the inner and outer flanges are *radial* or transverse to the shearing stresses. The effect is that these shearing stresses are very imperfectly resisted and the further effect of this is a deflection so great that the flanges, which should be in direct stress only, tension, or compression, are so bent as to have to act as beams, and they break from bending stress instead of from direct tension as they should. That is, instead of having one beam of the full depth of the yoke, from inside to outside flange, we have two shallow beams, each of the depth of one flange and its attached web. In fact, a yoke of this pattern to resist horizontal forces, is exactly analagous to a bridge consisting of a top and bottom chord, with some vertical

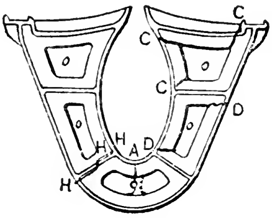

Fig. 3.

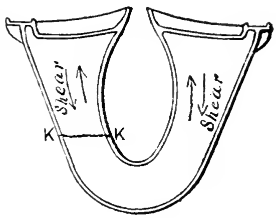

Fig. 4.

posts, all cast in one piece. It is absolutely essential to both strength and rigidity, especially for the latter, that these shearing stresses should be resisted.

A further defect in designs, shown in Figs. 1 and 2, is the angle in the outer flange at bottom. This flange is in tension, both on sides and bottom and yet this direct tensional stress has to be transmitted around an unsupported right angle. It is one of the first fundamental principles in designing to *avoid carrying stresses around corners.* A direct stress refuses to turn a corner quite as peremptorily as a ray of light, and when we undertake to make it do so it simply takes the short cut, in which case it always gives rise to bending stress.

THE SOLID WEB YOKE.

It was for the purpose of resisting fully the shearing stresses that I designed the solid web yoke. This yoke has over twice the strength and more than three times the stiffness of the best form of open yoke I have ever tested, and need weigh no more. It is the simplest way of overcoming these shearing strains, and is, I believe, the best pattern of yoke that can be made. Some engineers object to it because it offers no opportunity to bond the concrete through it, as is the case with the open web yokes. The necessity of this I cannot see, inasmuch as the concrete is continuous from one yoke to the next, and is held at the yokes by the projecting flanges.

To better illustrate the relative stiffness of the various designs shown in Figs. 1, 2, 3 and 4, I have selected the loads which cause a slot closure of ¼ inch in case.

Relative Stiffness of Cable Yokes.

Design.	Weight.	Load required to close slot-opening ¼ inch.	Relative efficiency, or resistance per pound of metal.
1	320	3,500 lbs	11.0 lbs
2	425	4,500 "	10.6 "
3	360	6,000 "	16.7 "
4	350	10,500 "	30.0 "
4	425	16 000 "	37.7 "

The last column of this table shows the relative efficiency of the various designs in maintaining the slot opening. It shows the solid yoke to be from two to three times as efficient, per pound of metal, as the open forms of yokes.

SLOT RAILS AND THEIR FASTENINGS.

In case there should be a great force developed between the slot and side rails, as sometimes occurs, then the lateral strength of these rails and the strength of the bolts holding them to the yokes should be strong enough to resist it. In both cases, the strength is really the elastic limit, since distortion is the thing to be avoided. Two ⅞-inch bolts would give a combined elastic limit of 30,000 pounds, and this is not greater than should be provided. The slot rail should then carry this same load, distributed over the space between yokes, usually 4 feet, without permanent bending set The size of this rail, when the form is given, can readily be computed to carry such a load without permanent injury, and such computations should always be made.

DISCUSSION.

By Wm. B. Knight (February 20) :—I have been much interested in reading Professor Johnson's paper on the strength and design of yokes for cable railways, and in the results of careful tests made by him of actual yokes.

My experience and observation, however, in the construction of cable railways, and from watching their operation, leads me to differ with Professor Johnson as to what is the most advisable in the way of a yoke.

I question, in the first place, whether one of the objects of a yoke is, as stated by Professor Johnson, "to resist the action of all external forces;" and think that if the yokes answer the main purpose of holding rails and slot beams and carrying sheaves in relative position, together with a certain amount of stiffness, that this is all that can be reasonably expected of it. To undertake to provide against the action of the frost would, even if practicable, very largely and unnecessarily increase the cost of construction.

The yoke indicated by Fig. 1, which Professor Johnson's experiments show to be the weakest against fracture from pressure and closure, was designed by me in 1886. It was at that time the lightest weight cast-iron yoke for standard depth of conduit that had ever been used, so far

as I know, on any cable railway work by nearly 100 pounds. In addition to this reduction in weight, I increased the distance apart of the yokes from 4 feet (which is the usual distance) to 4½ feet. Further than this, instead of using for the cable conduit tube a concrete made entirely of Portland cement as customary, I used in the lower half of the tube a concrete made of Kansas cement, and Portland cement only for the upper half. These modifications from usual practice effected a very material saving in the cost of construction, and it seemed to me would meet all the practical requirements of a first-class track, with proper treatment of special conditions along the road.

The first line of this kind built was the Wyandotte extension of the Fifth street cable line (Metropolitan Street Railway Company) in this city, comprising about 4½ miles of single track, which was put into operation early in the winter of 1887, and has been in continuous and successful operation without an hour's delay since that time. There has been practically no trouble or expense incurred in keeping the slot open on this line, except in two or three places where local conditions would, in my judgment, have operated to produce the same result with any form of yoke.

The Twelfth Street Line of the Metropolitan Street Railway Company's system was built during 1887, and the winter of 1887–8. It was put into operation in April, 1888, and has about eight miles of single track built with the same kind of yoke and construction as in the other case. This line has also been in continuous and uninterrupted operation since then, and a careful examination of this line, like the Wyandotte extension, shows no closure, or tendency to slot closure, except in certain localities very limited in extent.

The Eighteenth Street Cable Railway of the Metropolitan system, comprising about 6¾ miles of track, was built with the same yoke, but has the tube generally of Portland cement concrete throughout, owing to the very wet character of the soil through which it is constructed. This line has also been in continuous operation without interruption, and without any slot closure whatever since it was completed, November 1, 1888.

I think the practical results thus indicated, after a year or more of actual use on different lines, indicate the correctness of the theory which led me to adopt this lighter form of yoke. In this connection it may be interesting to mention the fact that in the course of the construction of the Fifth Street Cable Railway it became desirable, in order to avoid a large gas main, to cut away the bottom part of the yokes, and even to actually break them in two across the bottom. About 1,000 feet of track was constructed in this way opposite the Union Depot in this city, and there has been at this particular point absolutely no trouble whatever with the slot, which maintains its ¾-inch with remarkable uniformity.

My observations and examinations as to the causes of the closure of the slots of cable railways lead me to the conclusion that it is principally due to the saturation of the ground in which the tube is constructed, and that a thorough system of sub-drainage by agricultural tile drains will generally be found an effective remedy with even light yokes and an inferior quality of concrete; and further, that increasing the

weight of the yoke, or changing its form and construction and cost to secure greater rigidity against lateral pressure, will not prevent a closure of the slot from the action of frost.

The fact should also be remembered in considering the best form for a cable railway yoke that the slot *opens* as well as *closes:* and although it is of the most importance perhaps to the railway company to keep the slot open wide enough for the grip to pass through at all times, yet at the same time it is objectionable, and results in costly damage suits if the slot opens beyond the legal $\frac{3}{4}$ inch or $\frac{7}{8}$ inch. This opening, I think, will generally be found to occur at the same points on the line where the most trouble is experienced from the closure of the slot.

I think a perfectly satisfactory track could be constructed, if desired, without any yoke at all by simply forming the tube of Portland cement concrete, larger in section than usual, thoroughly sub-drained, and having suitable iron plates securely anchored in the concrete to which the rails and slot beams would be properly fastened.

By J. B. Johnson (March 20, 1889):—The causes which act to close a slot opening in a cable road are doubtless more or less local in their character. No slot opening ever varied uniformly in opening and closing. When Mr. Knight says, therefore, that trouble has been experienced only at isolated points on his lines, he only voices the almost universal experience. But when he supplements this statement by saying that in his judgment a stronger yoke would, in these instances, have served no better purpose in maintaining the slot opening, he would appear to state that the resistance of a structure to a distorting force is no function of its strength; he further reinforces this view of the case by affirming his belief that a conduit would be just as satisfactory without yokes as with them. The yokes do certainly add greatly to the lateral strength of the conduit, but if this strength is a matter of no consequence, then the yokes would seem only an expensive luxury, and should certainly be dispensed with altogether. Perhaps only an actual construction of a cable road without yokes which satisfactorily maintains its slot opening will convince an incredulous public that yokes are unnecessary. In the meantime most people will doubtless infer that the stronger the yoke the more it will be able to resist the action of the closing forces, and that if twice or four times the strength can be had for the same money, by simply changing the design of the yoke pattern, it is the part of wisdom to do so. Both the Cable and Western, and the Citizens' cable roads of this city have been greatly crippled from slot closure. The Missouri cable road has avoided trouble only by having a considerable room for adjustment by the removal of shims between the slot rail and yoke. The Citizens' road, not having this adjustment, has planed off $\frac{1}{4}$ inch from one of the slot rails on nearly the entire 12 miles of single track at a cost of $25,000 to $30,000.

The Cable and Western yoke is made of railroad rail iron and they wedge it apart when it closes, which it does every heavy freeze after a rain. Their yoke is *very flexible* and the Citizens' road yoke has

strength of only 6,000 pounds and closes 0.57 inch at 5,000 pounds. The Missouri Railroad Company's yoke is stronger and they have correspondingly less trouble.

What strength of yoke would be necessary to maintain a slot opening under all conditions cannot be known, but both theory and experience would lead us to conclude that the resistance to closure would vary directly with the strength of the yoke and conduit combined, and that therefore the greater this strength the better, especially when it is obtained with no appreciable increase of cost.

The solid web yoke cannot be made much lighter than 350 pounds, but with the greater strength thus obtained in the yoke, the same strength of conduit could be had with a weaker concrete. If Portland cement has been used with a weak yoke, then some cheap natural cement, as Louisville, Utica, or Rosendale, might be used with the strong yoke, without lessening the strength of the conduit as a whole. In this way one could obtain twice the strength for the same money, or he could obtain the same strength for much less money.

It is important to know just how the cast-iron yoke and the concrete conduit act when combined into one structure, as they are in the cable railway. We will examine their relative action both as to strength and as to stiffness.

Relative Strength of Conduit and Yoke.

From experiments made by the writer on concrete beams 10 inches by 10 inches by 66 inches long, two years old, the cross-breaking modulus of Louisville cement concrete, mixed 1 cement, 2 sand and 4½ broken stone, was found to be 200 pounds per square inch. For English Portland cement, mixed 1 cement, 2½ sand and 4½ broken stone, the modulus of rupture in cross-breaking was 350 pounds. If we take a Portland cement conduit 36 inches deep, where the concrete has a cross section of 12 inches by 12 inches at the yoke, and one of 36 inches by 6 inches deep between the yokes, their moments of resistance are 100,000 and 75,000 inch-pounds respectively, or 175,000 inch-pounds combined.

Taking the 350 pound solid web yoke, having a strength of 28,000 pounds, its leverage being about 36 inches from the bearing points to the neutral axis of the bottom, its moment of resistance is $36 \times 28,000 = 1,008,000$ inch-pounds.

The strength of the yoke is therefore nearly *six times* the strength of the concrete portion of the conduit when made of Portland cement.

Relative Stiffness of Conduit and Yoke.

If one material is much stiffer than the other, then the more rigid material will carry the greater part of the load until it breaks, when it all goes on the other portion.

At rupture the deflection of any solid beam varies as $\frac{f}{E\ h}$, where f is the modulus of rupture for that form of section and for that material, E is the modulus of elasticity, and h is the height of the cross section.

If we take the same average bottom depth of yoke and of concrete, then the deflections will vary only as $\frac{f}{E}$ at rupture.

We will take for cast-iron, $f = 20,000$ pounds (the section being I-shaped), and $E = 12,000,000$, while for Portland cement concrete we will take $f = 350$ pounds, and $E = 130,000$. This modulus of elasticity is taken from the Watertown Arsenal experiments on Portland cement concrete cubes in compression. The ratio of these two deflections at rupture would therefore be

$$\frac{\text{Deflection of concrete conduit}}{\text{Deflection of C. iron yoke}} = \frac{350 \div 130,000}{20,000 \div 12,000,000} = \frac{21}{16} = 1.6$$

That is to say, the concrete conduit would deflect 1.6 times as much as the cast-iron yoke, if both were of the same depth, and when both were ready to rupture.

If the depth of the concrete at bottom be less than the depth of yoke, then the relative deflection of the concrete would be still more than here indicated.

Also, if the concrete be made up of a natural cement its modulus of elasticity would be from 70,000 to 100,000, and hence its relative deflection, at rupture, would be more than here indicated.

It is safe to say, therefore, that a cast-iron yoke will always break before the concrete which forms the conduit, provided the yoke acts as a solid structure.

We now see not only that the yoke represents almost the entire strength of the conduit, but that this strength is first developed under the action of the closing forces, the full strength of the conduit not being developed until after the yoke has broken.

So far, therefore, as the stability and uniformity of the slot opening depends on the strength of the conduit as a whole, almost to this same extent does it depend on the strength of the yokes. A weak yoke makes a weak conduit, and a strong yoke makes a strong conduit: or, in other words, as is your yoke, so is your conduit.

GEORGE ALANSON PARKER.

A MEMOIR.

By the Late Samuel M. Felton, Honorary Member of the Boston Society of Civil Engineers.

[Read April 17, 1889.]

George Alanson Parker, the son of Joseph and Esther (Chapman) Parker, was born at Concord, New Hampshire, on the 8th of May, 1822. He was one of thirteen children, and his parents being poor, his boyhood was passed in very straitened circumstances. But he possessed an extremely active mind, and from his earliest youth showed a love of study that was proof against every obstacle. At the age of eleven he left his home and went to Charlestown, Massachusetts, for the purpose of attending school. A year later his father moved to the same place, which thus became the home of his youth and early manhood.

Before he was fifteen a strong bent toward the profession in which his

life was passed showed itself in his precocious mind, and in April, 1837, he entered the office of Col. Loammi Baldwin as a draughtsman. The following winter, though not yet sixteen, he was appointed teacher of a public school in Charlestown. At the end of the term he again secured employment in Colonel Baldwin's office, with whom and with his successor, Mr. S. M. Felton, he remained until 1841, when he obtained a situation on the Concord Railroad. This, however, he soon resigned to try his fortune in the West, where he had been promised an appointment on the corps of General Wilson, the Surveyor General of Iowa and Wisconsin. Accordingly, in July, he set out upon what was then a difficult journey of thirteen days, only 150 miles of which could be performed by rail, to Dubuque. In this town, which he described as "a dirty hole, containing about 300 inhabitants, two-thirds of whom are little better than pirates," and where brawls and murders were of constant occurrence, he spent a year as deputy surveyor. In the winter he traveled up the Mississippi to Prairie du Chien, and explored the almost untrodden country beyond Fort Atkinson.

In the summer of 1842, the appropriation for the survey being exhausted, he returned to Charlestown. Shortly afterward he became a partner with Mr. Felton, who, as before mentioned, had succeeded to the office of Colonel Baldwin. Here for some years he was busily engaged in the duties of his profession. He made a large number of surveys for projected railroads, beside building several wharves, surveying and mapping the city of Charlestown, laying out the grounds of the State Prison and of the Bunker Hill Monument, and doing much miscellaneous work. Of the railroads which he surveyed or built the most important were the Boston & Plymouth and other portions of what is now the Old Colony Railroad, the various branches and extensions of the Fitchburg, the Housatonic & Berkshire, the Peterboro & Shirley and a projected railway from Springfield to New London. He found time also to serve on the School Committee of Charlestown, and to render valuable assistance as the chairman of a sub-committee charged with the organization of a high school for the city.

In September, 1848, he was appointed Chief Engineer of the Sullivan Railroad. Though begun some time previously, this road had made little progress, and its importance as a connecting link made its speedy completion desirable. To this task Mr. Parker devoted himself with the utmost energy. During the severe winter which followed, he labored incessantly and succeeded, though at a heavy cost to his health, in finishing the work by the succeeding spring. The next year he was called upon to report, in conjunction with the engineers of the Cheshire and the Rutland & Burlington railroads, upon a bridge across the Connecticut at Bellows Falls. His estimate of the cost of this work was so low that no one could be found to take the contract at a price approaching his figures. He, therefore, undertook the work himself. Owing to the severe floods which occur in the Connecticut, the building of the bridge was attended with much difficulty. By very careful preparations he was enabled to complete the piers and trusses without accident, though just in season to escape an unusully violent freshet. The successful and rapid construction of this bridge, and of the Sullivan Railroad, added not a little to Mr. Parker's professional reputation.

In April, 1853, with his family and his brother-in-law, Professor Felton, of Harvard University, he sailed for Europe. After traveling through England and upon the continent, Mr. Parker, leaving his family at Florence, set out with Professor Felton for the East. The ordinary routes of travel being interrupted by the approach of war, they obtained permission to make the voyage from Malta to Constantinople on H. M. S. Caradoc, the ship which carried the sealed orders that, a day or two after their arrival, sent the allied fleets into the Dardanelles and precipitated the Crimean War. The warlike preparations lent additional novelty to scenes always attractive in themselves, and, moreover, the acquaintances that the travelers had made on the Caradoc procured them admission to places not often open to tourists. Their stay in the East was thus unusually interesting, but for Mr. Parker it was a brief one, for, tiring of separation from his family, he soon returned to Florence. Here and at Rome he spent the winter of 1853-54, and in April set sail for home.

Although, from a reluctance to claim time and attention from others, he delivered none of his numerous letters of introduction, he met many of the people best worth knowing—Liebig, Humboldt, Thackeray, Mr. and Mrs. Browning, the Martineaus, Crawford, Powers, Forster, Rogers, Barry Cornwall among others—and in particular enjoyed the experience of more than once exploring the lanes and by-ways of London with Dickens.

In 1855 Mr. Parker became Superintendent of the Philadelphia, Wilmington & Baltimore Railroad. The plan then under consideration, of bridging the Susquehanna River, was his chief inducement to take this position, for, at all times in his life, routine duties were irksome to him. He accordingly made surveys and reports, and took some steps toward the construction of the bridge. The crisis of 1857, however, caused a a suspension of the work, and he resigned his position. His love of country life was always marked, and he now removed his home from Charlestown to Lancaster, Mass., where his father had for some years owned a large farm. The work of reclaiming land, planting and building became, and remained to the end of his life, a source of constant and unfailing delight.

In September, 1859, he became engineer in charge of the projected Southern connections of the Baltimore & Ohio Railroad at Washington. The great importance of this work had long been recognized, but the difficulties of circuitousness, cost and the necessity of a long ferry had seemed insuperable. Mr. Parker, however, solved them by a plan for a tunnel under the eastern part of Capitol Hill, and a railway over Long Bridge. The outbreak of the war put a stop to this work, and ended also the schemes, with which Mr. Parker had at the same time been occupied, for the development of railway communications in the Peninsula of Delaware and the eastern shore of Maryland. At this time he offered to raise a regiment of sappers and miners, to be officered by students of the old Charlestown office, but was informed by General Scott that the war would be over in three months, and such a regiment would not be needed.

The pressure of travel caused by the war increased the necessity for an

unbroken highway between the North and South, and, in the spring of 1862, work upon the Susquehanna bridge was resumed. Mr. Parker was made engineer, with Mr. Benjamin Latrobe as consulting engineer, and returned with his accustomed energy to the work. This bridge was in its day so considerable a feat of engineering that it merits a somewhat detailed description, which follows, condensed from one written by Mr. Parker.

The site chosen for the bridge was at a point nearly a mile above the mouth of the river, and four miles below the head of navigation and tide-water. The natural width of the river is about 3,700 feet. The engineering difficulties involved in the work were, principally, the unusual depth of water, the unstable nature of the bottom at certain points and the more than common violence of the ice-freshets caused by the accumulation of ice upon the extensive flats at the river's mouth. The river is divided into two channels by a bar extending from Watson's Island immediately above, the easterly one having a depth of 49 feet, and the westerly one of 25 feet. The currents of the river are normally vertical to the line of the bridge, and the bottom of the river consists for some distance from the eastern shore of a stratum of sandy alluvium, varying from two to ten feet in thickness and resting upon a layer of gravel and sand covering the primitive ledges of granite.

The bridge is composed of thirteen spans, seven of 250 feet, east of the draw, and five of the same dimensions west of the draw. The draw-span is 175 feet in length. The whole length of the structure is 3,273 feet. Its height is 25 feet and its width 22 feet 6 inches.

The piers are of solid granite masonry, sheathed from the bottom to the level of extreme high water with wrought iron. They terminate at each end in triangular starlings, which do not project like the ordinary plow-share ice breakers of American bridges, but have a concave outline at their salient edges. The piers have only to meet, when subjected to their greatest strain, a steady, crushing pressure, which is met by their inertia. An uncommon degree of inertia proportionate to bulk is secured both by their iron sheathing and by the material of which they are built,—Port Deposite granite,—which has a weight of more than 165 pounds to the cubic foot.

The eastern abutment and the six eastern piers rest upon pile foundations; the others are built upon solid rock. Seven of the piers are built in water over 20 feet deep, the tallest being pier No. 3, where the water is 39 feet deep. The means employed to build the foundations were of a novel character. They consisted of portable iron caissons, sunk upon prepared foundations, partly by the use of screws and partly by means of guide-piles. Where the foundations were of piles these were driven as far as possible and sawed off by a machine (devised by Mr. Parker), which, in 42 feet of water, did its work accurately, and at the rate of sixty piles a day. At pier No. 3, where the water was 39 feet deep, a construction wharf was built around the site, and the caisson fastened to a timber platform moving vertically on guides attached to the wharves. Screws 56 feet in length were inserted through arms extending from the platform, so that, by means of a simple turning gear upon the wharves, the structure was made to descend upon the piles.

The superstructure, originally designed to be of iron, was, owing to the great difficulty of procuring that material at the time, finally built of wood. The chords of the trusses varied in their dimensions to suit the strain imposed upon them, an arrangement made necessary by the great length of the spans. The upper surface of the bottom chord and the lower surface of the top chord were, therefore, curved instead of being straight, as usual in timber bridges.

Four years altogether were necessary to complete the bridge. In July, 1866, a violent tornado and waterspout almost entirely demolished the ten spans of superstructure which had been raised. At length, on November 26, 1866, the first locomotive passed over the bridge from end to end, and the great line of railway from north to south was no longer broken in halves. The entire cost of the work was nearly two million dollars, which, considering the high price of materials and the scarcity of labor during the period, was by no means extravagant.

Beside his work on the bridge, Mr. Parker, during the war, made considerable purchases of rolling stock and railway supplies for the Government, refusing all compensation for his trouble, and even paying his own traveling expenses. In the year 1865 he acted also as President of the Philadelphia, Wilmington & Baltimore Railroad. Having resigned his connection with the company in April, 1867, he gave the next three years to the completion of the Maryland and Delaware railroads already projected,—the Eastern Shore, the Dorchester & Delaware, the Wicomico & Pocomoke, and others, beside the Chester Creek Railroad in Pennsylvania. His opinion as an expert bridge builder was also in much request at this time. He served as Chairman of the Committee on Piers and Foundations of the Engineers' Convention held at St. Louis in 1867, to consider the great bridge over the Mississippi, and was called to testify before the Congressional Committee having in charge the plans for bridging the Ohio.

In 1870, refusing to represent any political party, Mr. Parker was elected to the Massachusetts Legislature as an independent. During his two terms in this body he performed much laborious and valuable service. As Chairman of the House division, he made a separate report upon the most important business before the Railway Committee of that year—the question of State aid to the Boston, Hartford & Erie R. R. In 1871 and 1872 he held the same position on the Harbor Committee, the work of which interested him greatly. In his second term, also, he wrote a separate report for the Special Committee on Narrow Gauge Railroads, which attracted much attention and brought him correspondence from all parts of the United States and Canada.

At this time he was occupied with the building of the Lancaster Railroad, the failure of which, through no fault of his own, was the severest trial of his business life. In 1876 he made surveys for completing the New York & New England Railroad from Waterbury to the Hudson. In the same year he was appointed a manager of the Vicksburg & Meridian Railroad, being especially charged with arranging the proposed connections between Savannah and Shreveport on the Texas Pacific Railroad. In May, 1879, he undertook the construction of the Charlotteville & pidan Railroad, which he completed in July of the following year. To

this period also belongs a scheme, devised by Mr. Parker, for crossing Boston Harbor by means of a bridge with a double draw of diamond shape, the plan for which mysteriously disappeared from the Boston City Hall, and was subsequently published as original in an English periodical. About this time he was engaged upon the former plan for the Washington connections of the Baltimore & Ohio, which, for some reason, were again abandoned. In June, 1882, he was appointed consulting engineer of that road, and made examinations of its new line to Philadelphia. The next year, however, disapproving of the route chosen for that work, he resigned his position.

The last work upon which he was engaged was the Zanesville & Ohio River Railroad, traversing the Muskingum Valley. This railroad, begun in 1885, he completed only a few months before his death. His useful and honorable life came to an unexpected end, after an illness of but a few hours, on the 20th of April, 1887.

Mr. Parker was twice married. His first wife was Miss Mary Evans, of Concord, N. H.; his second wife, who was Miss Harriet Newell Felton, survives him with her four sons and two daughters. The foregoing brief sketch of his life can give but little idea of his character. Born in humble circumstances, he owed his rise entirely to his integrity, his industry and his ability. Gifted with much natural aptitude for his profession, his work was marked by excellent judgment, by great skill in planning and by unwearied diligence in execution. His love of reading and study has already been mentioned. To the last it remained undiminished, and few men, indeed, could match his range of taste and information. Few members of his profession have had a more intimate acquaintance with the history and literature of its great achievements, or have appreciated more fully its dignity and usefulness. The kindred science of architecture, also, had great attractions for him. Many of the railway stations, which he designed early in his career, to this day hardly surpassed in convenience and simplicity, remain to attest his skill in this art. Delighting in everything pertaining to country life, his happiest hours were spent upon his farm at Lancaster. This place, bare and unattractive, like most New England farms, when it came into his possession, his taste and skill in landscape gardening transformed into a park, whose groves and avenues of trees remain a unique and worthy monument to his memory.

ERECTION OF IRON BRIDGES—CLEVELAND & MAHONING VALLEY RAILWAY, SECOND TRACK.

By James Ritchie, Member of the Civil Engineers' Club of Cleveland.

[Read May 14, 1889.]

The object to be attained in the erection of bridges on existing roads is to do the work in the least possible time and without danger or delay to the traffic of the road. The work of erecting the bridges on the second track of the Cleveland & Mahoning Valley Railway has subjected the company operating the road to no danger and very little delay. The following is a list of the bridges erected, the numbers omitted being

those bridges which had already been double tracked or were beyond the limits of the double track work.

Bridge No. 7 —1 span, 89 ft. 6 in. Riveted lattice deck.
" " 7¼—1 " 30 ft. 6 in. Plate girder through.
" " 7½—1 " 28 ft. " " deck.
" " 8 —1 " 59 ft. 3 in. " " through.
" " 9 —1 " 160 ft. Pin connected Pratt through.
" " 10½—1 " 35 ft. Plate girder through.
" " 11 —1 " 38 ft. 2 in., and 2 spans 11 ft. Plate girder deck.
" " 12 —1 " 96 ft. " 1 " 23 ft. 8 in. Riveted lattice deck.
" " 13 —1 " 55 ft. 6 in. Plate girder through.
" " 14 —1 " 29 ft. 6 in. " " deck.
" " 14½—1 " 27 ft. 2 in. " " "
and 34 spans beam girders from 4 ft. 6 in. to 15 ft. span for open culverts.

These bridges were built and erected by the Passaic Rolling Mill Company, of Paterson, N. J., according to the plans and standard specifications of the N. Y., L. E. & W. R. R. Co., approved by the Chief Engineer of the C. & M. V. Ry. Co.

The shorter span deck girders and the beam bridges were put in place directly from trains standing on old track. The material, as shipped from Paterson on flat cars, was taken to its proper location and slid into place by use of skids without the use of false work. The bridges 7, 9 and 12 required a complete false work, as will be explained. Bridge 7¼ was put in entirely new by use of the Erie Company's wrecking cars, which are fitted with hand power derricks. Bridges 8, 10½ and 13 consisted of a double strength plate girder, which was to replace the old girder on the side toward the new track, while the old girder taken out was used to support the outside of new track, thus making a three girder, double track bridge.

Bridge 11 is of three spans, plate girder, and is rather peculiar in its construction. It carries the railway across a street at Niles, Ohio. There is one span of 38 feet 2 inches and two spans of 11 feet. The intermediate supports are four iron columns on stone pedestals set so as to allow the sidewalk to be between the columns and the abutments at each end, and as the bridge has a double skew the appearance in plan is peculiar. This bridge was erected by the Erie wrecking car from old track, the columns being first lowered to place and the girders then lowered and secured to same.

Bridge No. 12 was shipped in sections, each truss consisting of three pieces, one of about 50 feet in length and two of about 20 feet each. This bridge was put in by the derrick cars and took about four days.

Bridge No. 9, being a single track through bridge, it was deemed best to replace it with a new two truss double track bridge of 17 feet more span than the old bridge, which was 143 feet. The old bridge was to be used on the Newburgh branch of the Erie Railway in New York. In preparing for the erection of this new bridge, a temporary pile trestle bridge was constructed to carry the new track across the river, which track was then connected at both ends to the old main track and all trains switched off on to temporary track. The old bridge was then removed from the abutments and shipped to its destination and the abutments were taken down and replaced with new masonry and foundations. The latter consisted of 12 inch piles 24 to 30 feet long, driven 2 feet apart on centres, capped with 12 by 12 inch oak timber, drift bolted to piles. The caps

were then covered with a floor of 12 by 12 inch oak, the top of this floor being 3 feet below the ordinary low water. The footing courses of the masonry were 24 inches thick and 13 feet wide on the main walls, diminishing to 9 feet in width at ends of wings. The height of the walls from foundation to bridge seat was about 20 feet and the ballast wall was 3 feet 6 inches high above bridge seat. The temporary bridge was used as false work for erecting the superstructure on the north side and a double row of piling driven on the south side to serve similar purpose. These supported a framework of posts and braces carrying an iron rail on each side of bridge on which a traveler ran the entire length of the work and far enough on to the banks to pick up the material from the ground or the cars and take to its proper position. As soon as the south track stringers were put in the track was put down and traffic transferred back to the old track, while the trestle work was taken out and the new track put in in its true location.

In putting in the girder of Bridge No. 8, both the derrick cars of the Erie Company were so broken as to be laid up for repairs, so that we would be delayed in the erecting of Bridge 7, which was the last bridge to be put in, and would have to keep the men waiting unless some other means of erecting were substituted. We therefore decided to use two steam shovels, then engaged in grading for the second track, and to put in the bridge on Sunday, as there were fewer trains running than on week days. A locomotive was employed to pull each shovel, and on Sunday, at 9:40 A. M., the two shovels took hold of the longest section of the truss (about 50 feet) and moved out on to the old bridge. At the proper place they were stopped, the derrick arms swung out and the section lowered on to the false work. By moving the shovels closer together, and taking a fresh hold, the section was swung out nearly to its proper distance and braced temporarily. The 20 feet sections were each handled by one shovel and lowered to place and secured by bolts to the centre section. The second truss was put in similarly and the sway bracing put in and bolted up temporarily. It was found that in putting in the false work, allowance had not been made for the height of the end castings, and that the centre was about 6 inches too low. While one engine was removing one of the steam shovels back to commence its grading the other shovel was made fast to a chain passed around the centre of the entire bridge, and with apparent ease lifted the whole weight (about 18 tons) clear of the abutments and swung it out about 20 inches beyond where it was first dropped, and lowered it to its proper position exactly. All that remained to be done was to replace the bolts with the rivets shown on drawings. The work was entirely finished as above at 3:45 P. M. Of this time the men took 30 minutes for dinner while waiting for a train at noon. The actual time worked was 5 hours and 35 minutes, which, compared with the work on Bridge 12, same span, shows the value of steam derricks over hand power. The entire cost of using the steam shovels for this purpose, including the crews of the shovels and of the two locomotives and the laborers employed by the bridge company, was $180, or about $10 per ton of iron work.

The steam shovels used in this work are those which have been almost universally used by our contractors in grading the second track, and are

known as the Barnhardt steam shovel and wrecking car. I have never seen better work done by them than was done in erecting this bridge, as they worked with ease and rapidity, and their engines answered quickly to orders to stop or go ahead, thus making it possible to do fine work in connecting the joints. Of course it was necessary to chain them down to the main track when swinging out the trusses, otherwise they might have been pulled off the bridge into the river. We blocked up one side and chained down the other, as the bridge was not wide enough to enable us to use the regular jack arms of the shovel. Had we used these shovels for erecting all our deck bridges and plate girders we would have saved considerable time, in fact have finished so much sooner that the additional cost of the shovels would have been more than offset by the reduction in the time of the laborers.

The time occupied in erecting the 11 bridges and 34 spans beam bridges was three months, or from December 1, 1888, to March 1, 1889.

DISCUSSION.

Mr. C. G. Force: How long was that longest plate girder?

Mr. Ritchie: Fifty-nine feet was the longest plate girder taken all in one piece.

Mr. A. Mordecai: Mr. Ritchie has not mentioned the largest bridge. It is a double track draw-bridge, 226 feet between the two faces. It is 220 feet between the end pins. The bridge rests entirely upon the rim of the turn table. It is not centre bearing. There is no weight at all on the centre pin. It is very easily moved. We had rather a singular experience in putting it in. The turn-table was erected in the shop. The arms were turned upside down, and when they came to erect it on the pier they got the arms in the right place: consequently, there was a difference in their length that gave the centre pin a little rocking motion, so the arms had to be taken apart and made the same length. It shows the importance of getting a piece of work right in the shop before bringing it into the field for erection.

Mr. Ritchie: My reason for leaving out bridge 5 (Cleveland draw) was that I had no charge of it, as the N. Y., L. E. & W. R. R. Co. put it in.

Mr. C. H. Strong: I understood Mr. Ritchie to say that 59 feet is the length of the girder, what is the depth?

Mr. Ritchie: The depth is about 5 feet. The long plate girders were put in with the hand derrick, the short girders were put in on skids.

Mr. W. P. Rice: What is the horse-power of one of these steam derricks?

Mr. Ritchie: I do not know. It is claimed that they will lift 20 tons 14 feet out.

Mr. S. J. Baker: Are these bridges only put on to the second track?

Mr. Ritchie: The deck bridge were put under the second track only. Through bridges were built for both tracks.

Mr. Porter: As I understand it the railroad company bought these bridges by the pound and erected them.

Mr. Ritchie: No, they were bought by the pound erected.

Mr. Porter: Is not half a cent a pound a large price for erection?

Mr. Ritchie: We did not figure that out—the bridge company paid for them.

Mr. W. H. Searles : If Mr. Ritchie would make a blackboard sketch of Bridge 9 and explain the plan of operations it would illustrate his paper.

(Mr. Ritchie makes blackboard diagram and explains.)

Mr. Ritchie, pointing to diagram: Here was the old single track bridge. A temporary trestle was built across the river on the north side of the old bridge, and a second track was laid on that trestle. As soon as this was completed and ballasted, trains were switched off on that track, and the old bridge was taken down, loaded up on cars and sent away. The old abutments were then taken out, and the new west abutment was relocated in the same place as the old abutment, the east abutment being 17 feet east of the old east abutment.

This temporary trestle, which was a little too far north for the finished location, was thrown in towards the old track, so that the tracks would be the standard distance apart—13 feet centre. A stringer was laid on posts put up resting on the caps. (Referring to sketch.) Suppose this to be the stringer along here,—on top of that was another line of stringers on which was a rail carrying a truck. On the opposite side of the bridge was driven a double row of piling, and a similar arrangement of posts and braces was put up, and another rail on that side, and the entire width of the bridge was spanned by this traveling derrick, which would work both ways, longitudinally and transversely, so that finally all the pieces were taken out and put up by the derrick.

Mr. Porter: Was that derrick a kind of locomotive derrick ?

Mr. Ritchie: It moved the entire length of the bridge by hand.

Mr. Searles: What is the length of the span of this bridge ?

Mr. Ritchie: One hundred and sixty feet.

Mr. Mordecai: Is half a cent a pound about what you figured for cost of erection ?

Mr. Ritchie: That was the actual cost of putting in Bridge 7. The others were not figured.

Mr. Porter: I suppose that price was justifiable on account of time saved.

Mr. Force: Six dollars a ton is a pretty good price. As the work was done on Sunday I suppose you paid an extra price for the men.

Mr. Ritchie: No, we paid the regular price.

Mr. Barber: I have found a plan useful once or twice, the principal object being not to stop the trains; it consisted in designing a false work that would not interfere with either the old or the new bridge, putting the track on this false work and then removing the old bridge and replacing the new. Probably it did not cost more than an ordinary erection.

Mr. Mordecai: By using pile trestle for our false work it costs a little less than half a cent a pound, but we have never done it for $6 a ton; the least, I think, was $9.50, but there we did not drive any piling; the bottom of the river was hard.

Mr. Searles : I think the Club would like to see the plan of the Niles skew.

(Mr. Ritchie makes and explains diagram, showing one abutment skewed to the right and the other to the left.)

Mr. Baker : Why was it necessary to have the bridge skewed ?

Mr. Ritchie : In order to conform to the line of the street. The abutments have to conform to the street lines. There are three girders—one of 33 feet and six inches, and two at the ends of about 11 feet each. Each of the small girders was erected by a separate derrick. The derricks stood on old track. The material was lying on the bank there. We could not reach as far with these derricks as with the steam derricks.

S. J. Baker: I would like to ask Mr. Force what he thinks of putting the weight on the rim of the turn-table.

Mr. Force: I am opposed to putting a great proportion of the weight on the centre pin. The centre pin may carry the weight for a short time, but it is only for a short time. We have an example of this in the city on the Lake Shore bridge built by the Keystone people. They attempted to carry the greater part of the bridge on the centre, but failed. I favor putting a small portion of the weight on the centre and the major part on the wheels.

A Voice: Is the cost of the wood work included in the half cent a pound estimate?

Mr. Ritchie: No, merely the iron work. The wood work on the bridges is ties and guard rails.

Mr. Rice: I had rather a peculiar experience in building the highway bridge at Brooklyn and Brighton. I was limited in the amount of money and was forced to put two pedestals nearly over the crown of a arge arch culvert. I had only 10 days, and, from a superficial examination of the arch, knowing the load to be slight, I had no hesitation in making that location. As the work progressed I endeavored to procure drawings, and finally found one of the contractors and found the amount of backing that had been put in—there was perhaps 13 feet of clay. My first idea was to go down to the crown of the arch, but as I went down I found the material very stiff, so I left 4 feet of clay. I then found that the line of pressure went outside of the ring stones. I figured out the load of the bridge and the probability was that the arch would fail. I finally learned that after the arch was proportioned and built that some change was made there. I have no doubt that the clay is a very great assistance to the arch, but it has been a question in my mind what would be the lines of pressure. Would they be vertical lines? I think they would not be entirely vertical. Perhaps the pressure has been distributed laterally. While practically I had no doubt that the arch would stand, the figures indicated a failure. The arch is as good to-day as it was originally. I had to trust to practical judgment rather than to figures in this case, and the result is that the bridge stands firmly to-day. (Makes diagram.)

Mr. Force : The span of the arch is 45 feet and I built it. It is nearly a semi-circle. The ring courses are 24 inches. It was originally built with a 4-foot parapet wall for the county. It was afterwards necessary to raise the parapet wall.

Mr. Rice: I have never taken much stock in theories regarding arch or retaining walls.

Mr. Force: There is one view taken of the skew arch, which is, that

the pressure of the arch or any superadded load travels in a line with the face. I do not believe that. I believe that the weight goes to its nearest support. I believe that an arch is a unit. I do not believe that the pressure follows at right angles to the bed lines. That is a theory I could never swallow.

Mr. Searles: I think that ground may be well enough taken as regards the central portion of the arch, but near the face or ring stones we must provide for pressure that cannot go at right angles to the arch.

Mr. Force. If I had an arch to build I should not take any pains to build a skew arch; I would bevel the face and get the joints parallel with the axis of the arch.

SAN BLAS CANAL VERSUS PANAMA CANAL, AND SEA LEVEL VERSUS LOCKS.

By Wm. W. Redfield, Member of the Minneapolis Society of Civil Engineers.

[Read May 8, 1889.]

What I chiefly propose to do in this paper is to express a few of my own views in the matter, at the possible risk of being considered visionary. The latest scheme connected with the building of the canal (Panama) is that of the use of temporary locks, in order to expedite the completion of the canal sufficiently for vessels to pass through, and thus hasten the incoming of a revenue. That is all very well: but if *locks* must be used, why go to Panama for the route? Why not adopt that of Nicaragua in such a case?* Such would be the best route of all if locks *must* be used. But Nicaragua, good as its route may be, is at a point that makes a badly located focal point for converging and diverging lines of traffic thereon. By referring to any good map of the western hemisphere, this will be clearly seen. That is to say the Isthmus of Panama distinctly shows itself to be directly in the path of all shortest routes that would puncture this continent. Therefore, Panama or near by is the place for such work.

We have spoken of what the canal company is pleased to call "temporary" locks. I believe the word "temporary," as here used, when strictly interpreted, means "permanent." Then, of course, it follows that there will be no sea level project, and the scheme dwindles down to the construction of a canal in fact, instead of an artificial strait constructed by man. Now I hold that as things generally go, it will be almost physically impossible to change a lock-canal to a sea-level one after operation has begun; in fact, I see but one way in which it may be feasible. That is to excavate sufficiently wide through all the work so as to leave a level plain on either or both sides of the canal with locks. I think, even then, it will be found extremely difficult to construct a sea-level route alongside of one of greater elevation. But why be in such a hurry to have locks? Why is it not better to boldly say "sea-level or nothing," and work intelligently on that basis?

My plan would be as follows: To make the cross-section of the finished work to be a level plain at bottom about, say 6 feet above the highest

tide. This plain to be considerably wider at bottom than the top width of waterway of canal proper. If the vast tonnage passing through the Suez Canal is any criterion to go by, after the completion of the Panama Canal, a very few years will imperatively demand a widening of it. Such a cross-section permits this at any time. Again, imagine the "Chagres problem" to be solved; what better facility then, for a channel for the flow of all the side tributaries to the canal (the Chagres and the Rio Grande included)? Again, the great width at shore of canal facilitates the construction of artificial waterfalls for the Chagres and Rio Grande into cañons extending laterally into the bluffs just enough to give the water an easy and gentle flow into the side channels designed for them. But then comes the question, "What, make all that excavation?" I say boldly, yes, that is the only way to keep the rivers, cut by the route of the canal, permanently and satisfactorily out of the way of the canal. The number of cubic yards to take out is not the difficult part of the problem.

And now in regard to that "Chagres problem," that seems to be the *bête noir* in all the articles about the canal that I have so far read. What is it? Is it really to be feared as much as it is cracked up to be? If handled ignorantly, yes; but intelligently, no. I would suggest making a through cut as they go, keeping the bottom of said cut rigidly down to the required elevation above that of high tide; to do this at both ends of the canal; to excavate the artificial river beds on each side of this cut and in the bottom of same and as near as possible to and against the side slopes of the cut. As fast as a side tributary is encountered for the last time allow it to enter a side cañon by a water fall far enough away from the artificial channel to prevent wash and to enter the channel itself in a quiet way. Then the canal proper could follow; a pair of temporary lock gates could be used to keep back the sea water from where the canal proper was being excavated. When a mile was ready for water, put in a gate ahead of the finished part and let the water in. Then take out the gate back of the finished part, and place it where the next mile would end, and thus advance alternately with the two gates. At the same time let the excavations on top go on as fast or as far as practicable, in order to lessen the amount of face to be worked on, by the gangs at work on through-cuts. I see in a recent newspaper, a notice that a steamer has passed successfully along 15 miles of the canal from the Atlantic side. That fact alone, if it is so, ought to cause a rise in the stock of the canal company. The canal, if it *is* in a fearfully unhealthy country to work in, is no more so than was its predecessor, the Panama Railroad. In fact far less so, when the great disadvantages the railroad labored under are remembered. No facilities for getting about except the paths cut by hard labor through the dense tropical undergrowth. Now, this railroad itself renders the construction of the canal only to be a matter of time and money and men. The canal company has commodious hospitals for its sick. The present company may have failed. Money may come into the concern but slowly now or not at all. But all that does not make the completion of the canal (and that, too, on the basis of the plan I have given) an impossibility. Claiming, as I do, that the physical solution of the problem is

not out of reach, the financial part of the same will be sure to take care of itself. Rumors come from time to time (and there i undoubted truth in many of them) that affairs on the Isthmus are at a standstill. If this is so, is it not time for Americans to take hold of the scheme and make it a success, as the average American is sure to do with everything he undertakes?

Quite appropriately, and since writing the above, my attention has been called to a route, that in my view is superior to that of Panama, and yet so neighborly to the same that for location it is for the world's purposes practically the same. I mean the San Blas route, whose Pacific terminus is only about thirty miles east of Panama. This is a route that has been rarely mentioned, on account of just one objection. This is a tunnel seven miles long. But what, and where is this route? Let us examine it briefly. I have the honor to refer to the eminent W. W. Evans, in an article by him on the subject, from which I quote: "I will confine myself to three predictions. First, that Lesseps canal as a sea-level canal will never be built; second, that the Nicaragua Canal will be built, and by our own government or people; and third, that when the great importance of this water line to the world, and more particularly to our world, is once proved by the Nicaragua canal, then there will be a sea-level canal built on the San Blas route, *where it should have been built in the first place.* It presents the *shortest route from ocean to ocean*; it can be *cut in one straight line without a curve*; it is *not on a line of drainage*; it has *good harbors at each end*; it *can be traversed in less than one day*; it is *in a comparatively healthy region*; it has *every point in its favor but one*—namely, a tunnel big enough to pass a ship; and it has not yet got through the craniums of those wise men who have been sitting on this problem for so long a time, trying to hatch out something, that it is as easy to cut a ship tunnel as cut a railway tunnel, they only differ in quantity; and as regards this very tunnel there is not as much rock to be removed as there was in the 'Des Aguadero,' near the City of Mexico, which the Spaniards cut merely as a precaution, nearly 200 years ago, when their tools, their blasting compounds and their engineering knowledge were a mere bagatelle to what we now have at command."

I will now give a little information derived from an article in *Van Nostrand's Magazine* of June, 1869. A survey of the route was made in 1863, and a report thereof in 1864, on behalf of Mr. Fred. M. Kelly and others, of New York City, under the direction of A. McDougall, of Massachusetts, now deceased, as chief engineer, and Charles A. Sweet, of Syracuse, N. Y., as principal assistant. According to this survey the length of route from coast to coast is 30.03 miles. It extends from Chepillo Island on the Pacific coast (about 30 miles east of Panama), to the Gulf of San Blas on the Atlantic side. For convenience, the work may be divided into four sections. The first section extends from Chepillo Island to "Paneas" on the Bayano River, and is 10.101 miles long. Work required; a composite dam across the river at the Great Bend of the same; a tidal-lock at the Great Bend with walls 45½ feet high; a short canal cut across the Bend; removal of sand bars in Pacific Harbor and in Bayano River; and a light house at Chepillo Island. Estimated cost, including

draining, chopping, earth and river excavation, embankment, masonry, labor, materials, etc.: Removal of bars, $136,684; light-house, $12.000; tidal lock, $675,844; composite dam. $174.631; Great Bend cut, $209,835; total, $1,208,994.

Section 2 is a canal from Bayano River at Paneas, to the south end of the tunnel, and is 8.996 miles long. The work consists of the canal proper, and a new channel for the Mamoni River (crossed by route of canal), about 3.6 miles long. Estimate of cost : Canal, inclusive of bailing, draining, chopping, excavation, embankment, puddling, etc., $13,-033,943 ; new channel for Mamoni River, $115.752 ; total, $13,149,695.

Section 3 is a tunnel through the Cordilleras, 7 miles long. This is exclusively rock excavation. It consists of a canal of 25 feet depth of water, a perpendicular excavation of 29 feet above water surface on either side, from which springs an arch, forming the roof, and sufficiently high to pass over and clear the tallest masts. This section. at $2.50 per cubic yard, is estimated to cost $29,316,067.

Section 4 extends from the north end of tunnel to 25 feet depth of water in the Gulf of San Blas, on the Atlantic side, and is 3.073 miles long. The work consists of the canal proper, a lock with 9 feet fall and walls 38½ feet high, and a lighthouse on San Blas Point. Estimate of cost is :

Canal	$11,234,318
Lock No. 2 or lift lock	506,017
Light-house	12,000
	$11,752,335

Summary.

Section 1	$1,208,994
" 2	13,149,695
" 3	29,316,067
" 4	11,752,335
	$55,427,091
10 per cent. for engineering and contingencies	5,602,809
Medical and military aid, etc., interest on capital during construction, and transportation	32,500,000
	$93.529,900

This estimate is based upon a canal (except in tunnel) having a surface width of 143 feet ; at the bottom a width of 100 feet, and 25 feet depth of water. A second and cheaper estimate on a smaller size of canal is also given, which I shall not here repeat. Summed up, the general facts are: Entire route, except near the mountains, is nearly level; summit of Cordilleras varies under and over 1,200 feet above the sea; entire canal to be fed from Pacific Ocean and water maintained at the level of ordinary high tide in the Pacific. Tides in Pacific rise from 12.65 to 22 feet for highest. On Atlantic side there is from one to one and a half feet from ebb to flow.

From an article in the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for August, 1886, there is seen to be stated that an approximate estimate of work done on the Panama Canal, and work still to do tocomplete the same in eight years, in total, amounts in round numbers, with interest to same, $800,000.000. Now put these figures against the above estimate for the San Blas route, and there seems to be no doubt as to which is the best route. Take alone Mr. Evans' reasons "that it is not on a line of drainage, no Chagres problem to contend with, a good harbor at each end" (the Panama route has them not), and the other reasons given by him are sufficient to make the San Blas route the best. And

now, what about the chief objection raised against said route, to wit, a tunnel large and tall enough to float the largest ships? Is that enough reason to condemn a route when every other argument is in its favor? Has not the science of tunnelling advanced to such an extent in the last ten years, that the objection can be overruled? It would appear so. For instance, drive a small heading having its roof coincident with the crown of the arch of tunnel roof; sink as many shafts as practicable, so as to admit of more faces to work said heading. After headings are sufficiently advanced, keep adding forces to excavate on floors and sides of same, conforming all the time to roof and sides of large tunnel. Soon the work ceases to be tunnel-work, and becomes open excavation in tunnel. The work can be performed day and night, rain or shine, when outside work would have to stop. The wonder is that this route was not chosen instead of the one at Panama, the more one looks into it. Again, the seven miles of tunnel might be shortened to five, or even three, by enduring some open cuts of 600 or even 700 feet in depth near the portals of the tunnel. With everything else so much in its favor, it seems folly to shrink from what nowadays is no objection at all, that is to say a tunnel.

In conclusion, I would also suggest that after the canal was opened and paying revenue, a portion of said revenue might very wisely be applied each year to removing the roof from the tunnel, or, in other words, converting the tunnel into an open cut, and thus giving to the world a monument of American engineering skill, and a bona fide vindication and enforcement of the Monroe doctrine.

ENGINEERING.

ADDRESS OF PRESIDENT W. R. WARNER, OF CIVIL ENGINEERS' CLUB, OF CLEVELAND, MAY 14, 1889.

The work of the engineer is to develop the forces and materials of nature. Like the professions of theology and medicine, engineering has been divided into several schools, but unlike those professions each branch works in harmony with its neighbor, for are all working out nature's laws, and unfolding her secrets. Each victory gained by one gives new light to the others, and each depends largely upon the others, for they all are links in the great chain with which the world is moved.

The civil engineer of to-day is not content with building a railroad on a level plane; he has climbed the highest mountain ranges, reaching an elevation of over two miles, and has crossed the deepest gorges, with the iron tracks hundreds of feet in the air. He has tunneled the Alps for nine miles, connecting Italy and Switzerland, and has bridged the deepest and widest rivers with structures reaching one-third of a mile in a single span, over which 1,000 trains of cars are run in a single day.

The pyramids have been among the wonders of the world, and for ages were the highest structures ever erected by man, but the modern engineer has within five years doubled the height of the great pyramid, in the construction of the Eiffel tower in Paris.

Hand in hand with him works the mechanical engineer, who plans the steel works so that the iron ore from the mountains is taken from the docks by automatic machinery and dumped into the furnace, and then passed on from one operation to another, first iron, then steel, then the ingot, which is passed on to the rolling mill and turned out a complete rail 100 feet long, sawed into three lengths, and piled up ready for shipment, while still retaining the heat from the first furnace.

The mechanical engineer builds the locomotive and the express train of solid vestibuled cars, strongly clamped together like a continuous flexible car, in which the jar and vibration are almost eliminated.

The architect or building engineer is keeping fully up to the progress of other departments of engineering. It is true we have noble examples of the architecture of past ages, but for the most part they were the work of ages, for without our modern appliances and methods, a lifetime was not long enough to complete a building. Two hundred and fifty years elapsed between the commencement and completion of St. Peter's cathedral. The cathedral at Milan was 600 years in building, and a derrick on one of the towers of the cathedral of Cologne was a landmark for 400 years. A few months, or at a most a few years, are all that is required to construct our finest buildings, for the power of steam is utilized to raise all materials and place them in position. The new method of constructing the interior of our large buildings separate from and in advance of the walls, is meeting high favor. We have two excellent examples of this in the Arcade and the Society of Savings building in this city.

Another branch of special engineering is applied science, and in this department the civil, mechanical, architectural, mining, hydraulic and electrical engineer finds his strongest ally, for the investigator who works out the deepest problems of nature, and brings them within the realm of science, gives new tools and new instruments to work with, and thereby increases the possibilities within the reach of all departments of engineering.

The old unit of linear measure was a certain part of the earth's quadrant, but within the last two years two Cleveland scientists—members of this Club—have astonished the scientific world by going to the other extreme, and, taking the wave length of light as the standard unit, have demonstrated by ingenious appliances that by counting these wave lengths a standard linear measure may be produced, which can at any time be duplicated to within one one-millionth of its length.

The great advance in our understanding and use of electricity is due to invention and discovery in many branches of engineering science. Sir William Thompson, holding an incandescent lamp in his hand, truly said in a lecture on electricity, "A thousand inventions had to be made before this one was possible."

The members of the Civil Engineers' Club of Cleveland are all working earnestly, each in his specialty, each striving to contribute his part to the great sum total, which is the index of this most progressive age. In these meetings, we compare notes, tell how victories are won, caution each other on negative work, and thereby receive mutual benefit.

WATER SUPPLY TEST BY THE USE OF PRESSURE GAUGES.

By Robt. J. Johnson, Member of the St. Paul Society of Civil Engineers.

[Read February 4, 1889.]

It is sometimes a mooted question after a serious fire as to the adequacy of the water supply and the efficiency of the fire engines, which may require a test of the capacity of the water mains and a trial of the fire steamers to settle.

I will endeavor in this paper to give a few details connected with making such a test by using pressure gauges, and present a few practical formulæ suitable to use in performing the calculations.

The measurement of the flow in water mains by using pressure gauges is certainly not an exact science. The lack of accuracy in pressure gauges and the unknown quantities that enter into the question, such as the roughness and incrustation of the interior surface of the pipes; the untrueness to which they are cast, besides the difference in the formulæ of the various experimenters on the flow of water in pipes, render the results only fair proximations; but, nevertheless, if the test is carefully executed, the results will be essentially correct and fulfill all practical requirements.

Let the case be, first: The determination of the total capacity of an existing gravity system of water works within a stated district. Second: The ordinary domestic consumption within the district. Third: The efficiency of the system to supply a given number of fire steamers working at their full capacity. Fourth: The capacity of the steamers.

In order to obtain data for calculating the flow in the mains, a pair of pressure gauges must be attached to each of the mains which feed or draw from the district, the flow in the mains feeding and drawing from the district being considered as acting constantly in the same direction, there being, also, complete circulation in the pipes throughout the district.

The gauges should, if possible, be separated by as great a distance as one thousand feet, but if there are reasons which prevent so much distance, they should at least be placed at the extreme limits of one block, say from three to four hundred feet.

The larger the gauges used and the closer their graduation, the better the results that may be obtained, owing to the inaccuracies of the majority of small-sized ordinary pressure gauges, especially in measuring small differences of pressure in pipes, where the velocity is slight and the distance between the gauges is short. Fair results may be obtained by using an ordinary steam gauge with a five-inch dial, graduated to one pound (the intermediates to be estimated by the observer). For refined work, however, the gauges should have a dial not less than seven inches in diameter, and graduated as close as one-half pound.

All gauges that are to be used in the test should be first compared with a standard gauge, and their variations noted to be applied as a correction to the gauge readings taken during the test.

The gauges should be attached to the main by gas pipe of about one half inch in diameter through the top of the main, the lower end of the

pipe being brought exactly even with the inner wall of the main. Each gauge should be provided with a stop-cock to quiet the vibrations of the needle, and particular care should be exercised by the observer to reduce the oscillations of the needle to as slow a movement as possible, in order to be able to read the true pressure from the guages. The distance between the two gauges of each pair should be carefully measured and the elevation of the centre of all gauges on the mains taken and referred to a common datum.

The velocity of the flow in mains is measured by the loss in pressure between the two gauges of each pair, and this loss in pressure also indicates the direction of the flow. In order to be able to derive the actual loss in pressure caused by the flow into and out of the district, service pipes must be shut off, and draughts of all kinds closed between the two gauges of each pair during the progress of the test.

These preliminaries being completed the test for the volume of the ordinary domestic consumption may be proceeded with by stationing an observer at each gauge attached to the mains to record the pressure reading. The gauges should be read simultaneously (by a signal from a steam whistle, or other means), and in order to cover all inequalities of the flow in the pipes the readings should be taken at regular intervals of about five minutes.

The duration of this part of the test should be sufficient length to give a fair average of the ordinary domestic consumption and the ordinary volume of flow into and out of the district.

The formulæ for the velocity of water flowing in pipe with a given length and head (or in the case under consideration loss in head, which is equivalent) are both numerous and elaborate, those of Darcy, Poncelet, Chezey, Fanning, Neville, Weisbach, Kutter and Eytelwein being in most common use and highest approved.

Without entering into the discussion of the merits of the various formulæ. the formula, of Eytelwein, which has the support of many well-known hydraulic engineers, is here given :

$$v = 50 \sqrt{\frac{d\,h}{l + 50\,d}}$$

$v =$ velocity per second,
$h =$ head,
$l =$ length,
$d =$ diameter of pipe—all in feet.

Inasmuch as the experiments upon which this formula is based were made with clean, smooth pipes, free from all obstructions to flow, and laid to perfect alignment and grade, some modification of the co-efficient of the formula may be necessary in practice, the amount depending upon the conditions of the mains. Mr. Fanning gives a formula which is very nearly the same as Eytelwein's, the co-efficient being :

50 for clean pipes,
44.31 for slightly rough pipes,
36.60 for very rough pipes.

The domestic consumption and the volume flowing out of the district may be calculated by taking each pipe separately and taking an average of the pressure readings of each gauge ; taking the difference between

the mean pressure reading of the upper gauge and the mean pressure reading of the lower gauge—correcting for the difference of level, reducing to feet-head—thereby deriving the loss in head between the two gauges; use this quantity for h in the formula.

The mean velocity being found, the volume is equal to the velocity multiplied by the area of the transverse section of the main. Summing the volumes of the mains feeding the district, and likewise the volumes of those drawing from the district, the difference is clearly the volume of the water that has been taken from the mains within the district during the period of the test; *i. e.*, the domestic consumption.

The maximum capacity of each main delivering water to the district may be calculated by adopting the same formula for the velocity as before; take a mean of the corrected pressure readings of the gauge contiguous to the district, on each main feeding the district, reduce to feet head, and use this quantity for h in the formula, l being taken as the distance from the gauge to the entrance or mouth of the pipe. The volume of the water which is derived by this process is the maximum capacity of the mains above the ordinary domestic consumption and the ordinary flow out of the district. It is plain, however, that this volume of water will be delivered with an absence of pressure, the head being exhausted in delivering the water to the district; therefore, in determining the available capacity of the mains for fire service, the head under which the water must be delivered to the district must be deducted from the total head, as indicated by the mean pressure on the main.

The maximum head under which the water should be delivered to the district for fire service should be sufficient in each main to force the water into the valve chamber of a fire steamer coupled to the hydrant of highest level in the district, some allowance also being made for the contingency of excessive domestic consumption.

The formula, $v = 50\sqrt{\frac{d\,h}{l + 50\,d}}$, is not strictly correct for calculating the maximum velocity in the mains, as it neglects the resistance of entrance head and velocity head; but where the distance to the entrance of the pipe is over a thousand times the diameter of the pipe, the entrance head and the velocity head will be so small that neglecting them will not vitiate the result for practical purposes.

Previous to commencing the trial of the steamers, a pressure gauge should be fitted to the nozzle of each line of hose that may be used during the test, and also pressure gauges should be attached to all hydrants that are to supply water to the steamers during the test. The nozzle gauges should be fitted as near the end of the nozzle as practicable, in order to eliminate as much as possible the frictional loss between the gauge and the end of the nozzle, as the formula given for the efflux of nozzles is based upon the pressure being taken as the orifice of discharge. The steamers may now be connected with the hydrants and put into action, observers being stationed at all of the pressure gauges attached to the mains, hydrants, hose nozzles and steamers, the pressure readings being taken in the same manner and intervals as before.

The trial of the steamers should be continued a sufficient length of time to thoroughly try their powers, as well as the adequacy of the sup-

ply of water being delivered to them, say, from three to six hours. The minimum pressure required under which the water must be delivered to the steamers being zero, the hydrant gauges will indicate whether the mains are standing the draught on them or not during the test, providing, however, that the steamer does not draw the hydrant dry and produce suction, thereby causing the hydrant gauge to indicate a fictitious water pressure, to detect which the study of the gauge readings on the steamer, hydrants and nozzles will serve as an index. Noting the positions of the pressures at the various stages after the steamer has been put into action, in the event of suction occurring, the discrepancy between the steamer and the hydrant pressure, as compared with the nozzle pressure before and after the suction, will be so marked that if suction exists it can be easily discerned.

The ability of the steamer to exhaust the main, depends to some extent upon the length of hose from which they throw their streams, on account of the large frictional resistance in hose, which causes a loss in pressure of from 10 to 25 pounds to every hundred feet of hose for an efficient fire stream (according to the kind and condition of the hose and the pressure the stream is under). In view of this circumstance and the fact that the length of hose that would be required in case of fire is variable, it would seem proper to test the steamer with both a short and a long length of hose, of which, by the short length of hose, the mains would be most thoroughly tested and by the long length the weakness of the steamer (should it exist) would be developed.

The quantity of water drawn from the mains by the steamers during the test may be calculated in two ways (one checking the other). First, by the method pursued in computing the domestic consumption; and second, by using the data obtained from the pressure gauges attached to the hoze nozzles.

The quantity of water discharged from each line of hose having a ring nozzle may be calculated by taking a mean of the pressure gauge reading on the nozzle, reducing to feet head and using for h in Weisbach's formula for efflux from a circular orifice in a thin plate, which is:

$Q = A\ C\ 8.025 \sqrt{h}$

Q = discharge in cubic feet per second.

C = co-efficient of efflux = 0.615 (Weisbach).

A = area of orifice in square feet.

h = head in feet.

The quantity of water discharged from each line of hose having a smooth-bore nozzle may be calculated by the formula given above for the ring nozzle, using, however, Weisbach's mean value for the co-efficient of efflux for smooth nozzles, which is $C = 0.97$.

The foregoing is given as a mere outline; the execution of the test being governed largely by local conditions and requirements, which may demand other and more refined treatment than that indicated; but for practical purposes, dealing with a subject that has so many points of indefiniteness attached to it, the methods as given would appear to give results as close as the case demands.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

MAY 15, 1889:—A regular meeting was held at the Society's rooms, Boston & Albany Railroad Station, Boston, at 19:30 o'clock, President FitzGerald in the chair. Fifty-four Members and eight visitors present.

The record of the last meeting was read and approved.

Mr. Waldo E. Buck was elected a Member of the Society.

The following were proposed for membership: Charles H. Bartlett, Manchester, N. H., recommended by J. P. Snow and Louville Curtis; Frank E. Hall, Quincy, Mass., recommended by Dexter Brackett and R. C. P. Coggeshall; Fred S. Hunter, Boston, recommended by M. M. Tidd and S. E. Tinkham, and Hiram Nevons, Cambridge, Mass., recommended by E. D. Leavitt and Dexter Brackett.

The President announced the membership of the Committee on Excursions: Edward W. Howe, Albert F. Noyes, George A. Kimball, Lawson B. Bidwell and C. Frank Allen.

Mr. Tilden, for the Committee on Common Headquarters, presented and read a very full report upon the practicability of occuping headquarters in common with other scientific societies located in Boston. The report summarized the information which has been collected as to the numbers and requirements of many of the scientific associations of the city, and stated that there is a movement in progress for the erection of a building on the Back Bay, which should accommodate various organizations. If this project should not succeed, a more modest scheme for a small number of the societies would be to adapt a dwelling-house to their requirements. The report was accepted, and on motion of Mr. Allen it was voted to continue the present committee, with the addition of a new member, to be selected by the President. The President selected Mr. Eliot C. Clarke as the additional member.

Mr. Allen, for the Committee on Excursions, made a verbal report, calling attention to the fact that there are, from time to time, works of engineering interest in progress which could be and would be visited privately by members of the Society if the matter was properly called to their attention. Such works would have in general only temporary interest and would not interfere in any way with the regular excursions. As examples can be mentioned the erection of the roof of the Armory Building lately put in place, and the work of lowering the heavy granite columns of the Merchants' Exchange Building on State street. It was suggested that the monthly notices of meetings should include a list of "Works of Interest in Progress." To make this of the most value it would be necessary to have the co-operation of each member in informing the Secretary or the Committee of any such works in progress.

On motion of Mr. Manley, it was voted, that the Committee on Excursions be authorized and requested to embody their verbal report in the notice of the next regular meeting, and to commence the announcement of points to be visited at the same time.

Mr. John A. Gould, Jr., then read a paper describing the High Service System of the Boston Water-Works, with particular reference to the new pumping plant at Chestnut Hill and the new Fisher Hill reservoir.

The paper was discussed by Messrs. Brackett, FitzGerald, Rice and Stearns, and Mr. Evans spoke briefly of the sliding of the paving of the Lowell reservoir, which occurred in 1886.

Mr. Charles E. Haberstroh read a paper giving a description of experiments recently made to determine the co-efficient of flow through the large gates used on the Boston Water-Works.

[*Adjourned.*] S. E. TINKHAM, Sec'y.

ENGINEERS' CLUB OF ST. LOUIS.

MAY 1, 1889 :—307th Meeting.—The Club met at 8:10 P. M. in the Polytechnic Building, thirty-three Members and four visitors present. Vice-President Nipher in the chair. The minutes of the 306th meeting were read and approved. The Executive Commitiee reported the doings of its meeting of same date, announcing that Wm. D. MacQuesten had been dropped from the rolls for delinquency; also recommending C. H. Howard and Pope Yeatman for election to membership. They were balloted for and elected. Applications for membership were announced from Thos. J. Long, Western representative of the Union Bridge Company, and O. H. Schramm, Kansas City representative of the Pond Engineering Company. The Secretary announced that Wm. J. McNulty had qualified.

The Librarian announced the receipt of Whipple's book on "Water Supply," and the report of the New York Aqueduct Commissioners on the Quaker Bridge Dam.

Mr. S. B. Russell offered the following :

Whereas, The collection and exchange of data is a proper mission of the Club;

Resolved, That the Executive Committee be instructed to compile a book of local data, to be presented for publication at the next annual meeting, the book to contain such information in regard to the materials of engineering in use in St. Louis and vicinity as can be collected, and other memoranda of a local nature, useful to engineers. The committee to call on such members as it may select for assistance in the compilation.

Mr. Holman amended this resolution, substituting a standing committee to be appointed by the chair in place of the Executive Committee. The resolution as amended was then adopted. The chair appointed on this committee S. B. Russell, Robert Moore and John B. Johnson.

Prof. H. B. Gale then read a paper on a new theory of "Chimney Draft" and the design of "Brick and Iron Stacks." The author had made numerous experiments to determine the different factors which entered into the problem and gave some formulæ in shape for convenient use. The difference between brick and iron stacks was discussed. He showed that while the area of a stack could not b reduced below certain limits, it could be increased without affecting the efficiency of the stack. Professor Johnson, Mr. Holman, Mr. Laird, Nils Johnson and Mr. Bryan took part in the discussion.

The hour being late, it was ordered that Mr. Seddon's paper on "Experiments on Settling Water" be deferred until the next meeting. After some informal discussion of meeting places the Club adjourned.

W. H. BRYAN, Secretary.

May 15, 1889:—308th meeting.—The Club met at 8:10 P. M. in the Polytechnic Building, President Meier in the chair, forty-three Members and six visitors present. The minutes of the 307th meeting were read and approved. The Executive Committee reported the doings of its meeting of same date, recommending T. J. Long and O. H Schramm for election to membership. They were

balloted for and elected. The Secretary announced that C. H. Howard and Pope Yeatman had qualified as members.

President Meier read a memoir of the late Col. Henry C. Moore, an ex-president of the Club. The paper covered the principal events in Colonel Moore's life of interest to engineers. He had been a very busy man, and connected with some of the most prominent railroads in the country.

Mr. J. A. Seddon read a paper describing experiments he had made concerning the "Settling of Water" in the settling basins of the St. Louis Water-Works. His paper was illustrated by numerous drawings. He also explained in detail the manner in which his experiments had been worked up and the resulting conclusions. It was ordered that the discussion of this paper be made the special order for the next meeting.

Prof. J. B. Johnson presented a paper on trussing the Fagin Building against wind pressure. The hour being late, the paper was not read, but the professor gave a verbal outline illustrated by sketches on the blackboard. It was shown that the principal danger was from wind pressure from the east. This had reached 40,000 pounds on the exposed east face of the building, and this was supposed to have thrown the building out of plumb. Professor Johnson described the manner in which the building had been righted and the manner of trussing it permanently. The trussing had been calculated to withstand a wind pressure of 30 pounds per square foot, and was now considered even safer than ordinary buildings. Messrs. Holman, Moore and Ed. Flad took part in the discussion. It was shown that very few architects took any account of wind pressure in designing buildings. Col. Meier explained a somewhat similar case at the Armory building, where it had been found necessary to put in trusses for the same purpose. Mr. Holman spoke of pulsations o wind pressure which produced a cumulative effect, as noticed on stand pipes and brick stacks.

Prof. F. E. Nipher made a verbal report on a recent investigation into the performance of an engine working at a fixed cut-off without governor. Measuring the brake horse power, the pressure of the supply steam and speed, he finds that the performance of the engine is represented by an hyperbolic paraboloid, in which the lines of constant load and the lines of constant speed are rectilinear elements. At any fixed pressure the relation between output and speed is represented by a parabola, the vertex of which represents a condition of maximum output.

The condition of maximum output at any pressure is, that the moment of the force on the brake arm must be one-half that moment M' which will bring the engine to rest, while the speed must be one-half that speed n' which the engine would have if the load were entirely removed. The maximum output is then in horse-power $\frac{\frac{1}{2}\pi}{33,000}M'n'$

Professor Nipher stated that he should proceed to determine whether mean effective pressure might be substituted for pressure of supply steam. His present opinion was that it could. In that case indicated horse-power could be represented as a function of the same co-ordinates, P and n. The equation for indicated horse-power is :

$$P\,n = \frac{33.000}{2\,\pi\,R^2\,l}\ (\text{I. H. P.})$$

Where R is piston radius and l is stroke.

This is also an equation of the hyperbolic parabolic, the axes of which are in an entirely different position from those of the surface of brake horse power. Both surfaces contain the pressure axis. The difference between the two horse-power ordinates will give the real engine friction for any load and speed.

It follows from these equations that the work consumed in the friction of an engine is constant for all loads, if the speed is constant.

It was discussed by Messrs. Holman, Gale, and Ed. Flad.

[*Adjourned.*] Wm. H. Bryan, Secretary.

MAY 29, 1889:—309th Meeting.—The Club metat 8:10 P. M. at the Elks' Club, President Meier in the chair, 19 Members and 5 visitors present. The minutes of the 308th meeting were read and approved. The Executive Committee reported the doings of its meeting of same date. The Secretary announced the receipt of some valuable contributions to the library. He also read a report from the Chairman of the Association of Engineering Societies to the effect that the ballot on the proposed first amendment to the articles of association had resulted as follows: For, 8; against, 0; not voting, 3.

On motion of Mr. Seddon, the action of the Board of Managers was ratified by this Club, Messrs. Moore and Holman discussing the matter briefly. The Secretary read a communication from the St. Louis Public Library on the subject of memberships and permanent meeting place. This question was discussed at some length by Messrs. Johnson, Holman, Seddon, Gale, Moore, Bryan and Bouton. The matter was finally left in the hands of the Executive Committee, with the understanding that a letter ballot would be taken.

Mr. P. M. Bruner read a paper on a new system of "Fire-proof Flooring." He explained the requirements of the modern fire-proof building, and showed the objections to some of the most prominent systems in use. A number of tests had been made on the new flooring with excellent results. It had been used in the State capital at Jefferson City, and was now being applied in some St. Louis buildings. He also gave detailed particulars regarding manufacture, erection, durability and cost. Professor Johnson, Colonel Meier and Mr. Moore took part in the discussion.

The special order of the day was then taken up, being a discussion of Mr. Seddon's paper on "Settling Water." Professor Johnson presented a written discussion based on his recollection of the paper as read. He criticised at some length some of the methods employed and the results secured, and also gave credit for certain data, which the paper contained, and which, in his opinion, were of great value. He thought the disturbing effect due to the energy imparted to the water on entering the basin, and also the effect of the wind, were greatly underestimated. The professor also explained what he considered to be the advantages of the plan of continuous settling and of covering reservoirs. Mr. Holman explained the experiments on this subject made by Colonel Flad several years ago, which had resulted in unfavorable conclusions. The principal difficulty with St. Louis water was due to the fact that the reservoirs could not be cleaned as often as necessary; and, furthermore, they were required to do about double the work which they were originally intended for. Mr. Holman also gave some particulars of the different kinds of sediment contained in the water at different seasons of the year. The sediment coming from the Mississippi and Missouri rivers were very different. He stated that the Missouri River water was always more impure than the Mississippi. Colonel Meier, Robert Moore, Professor Gale and Messrs. Seddon and Ferguson also took part in the discussion, after which the meeting adjourned.

WM. H. BRYAN, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

MAY 14, 1889:—President W. R. Warner in the chair; 21 Members present.

Minutes of last meeting read by the Secretary and approved.

Messrs. A. Mordecai and Thos. West were appointed by the chair to distribute ballots and act as tellers in election of members.

The following were elected to active membership: Messrs. J. B. Yates, P. S. A. Bickel, J. E. Pettee, R. Gurley, A. P. Ruggles, F. E. Gribben.

A paper received by Mr. W. P. Rice, from Civil Engineers of the State of Ohio, addressed to the General Assembly, was read by the president, petitioning for legislation upon the qualifications of county surveyors.

Copies of a paper sent by the Civil Engineers' Club of Chicago were distributed to Members; also a new list of officers and members of the Civil Engineers' Club of Cleveland.

As there was no further business, the President, Mr. W. R. Warner, read his address. At the conclusion of the address Mr. Warner stated that he had attended a meeting of the Philosophical Society in Washington on Saturday evening, and had specially noticed that four papers were mentioned on the programme, the time of each being limited. One was to occupy five minutes, one fifteen, another thirty-five, and the fourth a few minutes. He thought the Civil Engineers Club of Cleveland might be benefited by a similar arrangement. The reading of several short papers need not interfere with the special paper for the evening. Many of the members were habitually silent—perhaps they had not time to prepare long papers, but much interest might be the result of several short papers, if each contained a single telling item. Mr. Warner said that a pleasing feature of the Washington meeting was that he had been invited by no less than six different members who had met him on the street and pulled the programme out of their pockets. The interest this evinced might beneficially be imitated.

Prof. Morley considered the suggestion to have several short papers a valuable one, and hoped it might prevail. He thought that many of the members could profitably take up the time of the club for five minutes. For instance, he could make a brief report of progress in regard to Light Wave Measurements, while he would not desire to read a lengthy paper on a subject that had already been brought before the club. No doubt other members would be glad to make short reports of progress in their departments.

Mr. W. H. Searles said that he highly approved of the suggestion. The club was composed of many men of many minds and many pursuits—it contained not less than six classes of engineers, and the specialty of one class did not particularly interest the others. If all were civil engineers, they could listen to one paper of considerable length, but under the circumstances it would be better to have several papers on diverse subjects. Mr. Searles thought that the members as a rule examined the announcement for the evening, and if the paper mentioned did not specially interest them they decided to defer their attendance. If several items on several different topics could be presented, a much larger attendance might be hoped for, and all would be stimulated to a wider range of thought. This need not exclude the special paper of the evening.

Mr. Warner said that though it was true that men might be more interested in what came within the line of their daily work, yet it was of great benefit to meet others who were not in the same rut, whose modes of thought were different. Looking back over several years of the club he could remember many papers on subjects wholly apart from his line of work that he had heard with the keenest interest. Of course the responsibility for the programme rested with the various committees. The programme for the next meeting would be under the charge of the committee on Applied Science.

Mr. James Ritchie then read a paper on the Erection of Iron Bridges on the Cleveland & Mahoning Valley Railway, which was followed by discussion. The Club then adjourned.

JAMES RITCHIE, Secretary.

MINNEAPOLIS SOCIETY OF CIVIL ENGINEERS.

MAY 8, 1889:—Regular meeting in City Hall, Minneapolis. Meeting called to order with Vice-President Sublette in the chair. Minutes of previous meeting read and approved. Letter of resignation from E. T. Abbott read and accepted.

Regular literary programme of the evening consisted of a paper on the Panama Canal, by W. W. Redfield, and proved an unusually interesting one. It is to appear in the JOURNAL by vote of the Society.

The Secretary was instructed to see Wm. De Le Berre about the publication of his paper on compression of bran.

F. W. Cappelen instructed to spend the needed amount to prepare some concrete specimens for the Society. A promising programme was partly arranged for next meeting by Mr. Cappelen to form a part of the exercises at the formal opening of the north side pumping station.

[*Adjourned.*] W. R. HOAG, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

MAY 6, 1889 :—A regular meeting was held in the Club Room at 8 P. M., Vice-President W. H. Breithaupt in the Chair, Kenneth Allen, Secretary. There were present 7 Members and 2 visitors.

Minutes of the last regular meeting of the Executive Committee were read and approved.

On canvass of ballots, Robert A. Crawford was declared elected as Associate Member.

Mr. Sonne presented a final report for the Committee on Transfer of Members as follows:

APRIL 26.

The President and Members of the Engineers' Club of Kansas City:

DEAR SIRS : Your Committee on consideration of the question of transfer of membership begs to report as follows :

That inasmuch as engineers from the nature of their profession are often under the necessity of changing their place of residence from one part of the country to another, some arrangement for a transfer of membership between local societies is, in your Committee's opinion, eminently desirable.

A practical arrangement to this end could probably best be effected by having the Board of Managers of the Association of Engineering Societies, as now existing, thoroughly discuss the question and decide on some definite scheme, giving in full a *modus operandi* for transfer, which scheme should then be adopted, and embodied in its constitution and by-laws, by each of the societies in the Association wishing to join the movement. Initiation should also be extended to local engineers' societies of acknowledged standing not in the present Association to join in this transfer of membership arrangement.

Your Committee would recommend that your representative on the Board of Managers of the Association of Engineering Societies be requested to bring this question before the said Board for consideration at first opportunity, and would suggest the following as items in the scheme for transfer :

(1.) Only members of any class, in full standing, with all dues paid up, shall be entitled to transfer privileges.

Any such member wishing to transfer shall be given a letter or certificate by the President, or Vice-President, and Secretary of his Club, stating his class of membership, date of admission and general engineering standing as shown in his application for membership and subsequent record.

For such certificate a fixed moderate fee, say of $1.00, shall be charged.

(2.) On presentation of his certificate to the Club to which he wishes to transfer, and payment of difference in dues, both initiation and current, if greater in the new Club, the transferee shall at once be entitled in the new Club to all privileges except that of voting. He shall not be entitled to any rebate if dues in the new Club are smaller than in the one from which he comes.

(3.) After a stated period, say of six months, the transferee shall be voted on, in the new Club, for regular membership in his class, without, however, being required to put in a formal application. If then rejected, any moneys he may have paid to the new Club shall be refunded to him.

(4.) If at any time an engineer wishes to return to a club to which he previously belonged, after transferring to another as above set forth, he shall, on so returning, at once be fully reinstated as Member in the class to which he belonged.

Respectfully submitted, O. F. SONNE,
ARTHUR J. MASON,
W. H. BREITHAUPT.

On motion of Mr. O. F. Sonne it was voted that a copy of the report be handed to our representative on the Board of Managers, with the request to lay it before the Board.

The following resolutions to submit an amendment to the Constitution provid-

ing for a Second Vice-President to ballot were presented by the Executive Committee and adopted.

Whereas, At the last meeting of the Executive Committee of the Engineers' Club, the propriety and advisability of creating the office of Second Vice-President was duly considered and discussed; and,

Whereas, It was the unanimous opinion of the Executive Committee present that such a move would be to the interest and welfare of the Club; be it

Resolved, 1st. That the office of Second Vice-President be created.

2d. That the present incumbent of the office of Vice-President be known as First Vice-President.

3d. That whenever the wording of the Constitution and By-laws refers to and mentions the name of *Vice-President*, the words be changed to *First Vice-President and Second Vice-President.*

4th. That the Club proceed at once to the election of a Second Vice-President in harmony with the By-laws prescribing how and where officers or an officer shall be elected.

It was proposed to change the dates of regular meetings, but no action was taken.

On recommendation of the Executive Committee a Standing Committee on Cements and Mortars was appointed by the Chair, consisting of Messrs. D. Bontecou, W. D. Jenkins and E. Saxton.

On motion of Mr. Sonne the Chair appointed a committee, consisting of Messrs. Sonne, F. C. Gunn and Mason, to make arrangements for the annual summer excursion.

A paper on the "Foundations for the Liimfjord Bridge" was read by Mr. O. F. Sonne.

"The bridge was built in 1874-78 across the Liimfjord, near Aalborg, for the Danish State Railways; it has four spans of 206-226 feet and two draw spans of 88 feet each. The piers were sunk by the pneumatic process through soft and tenacious mud, one of them to 59 feet, the six others to 111'·55-113'·5 below m. w.; they were built with iron caissons, the masonry of hard burned brick laid in Portland cement, the upper part protected by granite; they were lowered from scaffolds and kept suspended, during the sinking, each by four rods or chains hooked around the cutting edge. Through a combination of circumstances one of the piers was overturned and it located on the centre line of the bridge; a new pier was lowered and had to be carried through the old one. The work was done under contract by the French firm Compagnie de Fives-Lille."

A. G. Glasgow was proposed as Member by F. C. Gunn, W. H. Breithaupt and Kenneth Allen.

[*Adjourned.*] KENNETH ALLEN, Secretary.

MAY 20, 1889 :—An adjourned meeting was held in the Club Room, at 8 P. M., J. A. L. Waddell in the chair, Kenneth Allen, Secretary. There were present nine Members and four visitors. Minutes of the last regular meeting were read and approved. As a quorum was not present at the meeting of the Executive Committee called May 13, the ballots were not canvassed.

A sample of binder for the JOURNAL was shown, but it was decided not to order them for the Club as a whole, but that individual members might supply themselves.

A paper on "The Inspection of Iron Bridges" was read by Henry Goldmark. He referred to the lead taken by our Club in highway bridge reform, but considers the safety of railroad spans of even greater importance. Even though the earlier long-span bridges are quite satisfactory, he considered a large proportion of the shorter spans on railroad lines as far from perfect.

The experience of the New York and Massachusetts Railroad Commissioners was referred to as corroborating this opinion. The author further pointed out the reasons and the remedy for this unfortunate state of affairs. The trouble, in his opinion, lies mainly in the fact that bridge designers, as a rule, see little or nothing of their work when it is in use. The remedy pointed out is a systematic inspection of all railroad bridges by specialists.

The paper was discussed by Messrs. Waddell, Stern, Filley and Farnsworth.

[*Adjourned.*] KENNETH ALLEN, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

APRIL 20, 1889:—The regular monthly meeting was held at the office of Mr. Beckler, First Vice-President, who, in the absence of the President, occupied the chair.

There were present Messrs. Haven, Robinson, Sizer, Foss, Kelley, Danse, F. J. Smith, Ellison, Keerl, and Chief Justice Blake as visitor.

The Committee on "Library and Permanent Quarters" submitted the following report:

To the Montana Society of Civil Engineers:

Your Committee on "Library and Permanent Quarters" would respectfully report that they have considered the advisability of incurring the expense of a suitable room for the use of the Society, and that they believe that under the existing conditions it would be a greater expense than we are at present warranted in undertaking.

Mr. Beckler offers us the use of his offices for all meetings, and will cheerfully allow the Society to place a portable book-case in his main office, where it will be readily accessible to members at all times.

Your Committee would recommend that the Society purchase a book-case adequate to its probable needs for the ensuing two years, and avail itself of Mr. Beckler's offer.

Your Committee would further recommend that a committee of four, consisting of one each of the representatives of the following branches of the Society, viz.: One civil engineer, one mining engineer, one mechanical engineer and one architect be appointed to expend from the existing funds of the Society a sum not exceeding $60 for the purchase of suitable books for its library, and that the members of the Society be invited to contribute any books or technical periodicals which they may desire to give for its benefit.

Respectfully submitted,

JOHN HERRON,
JOHN GILLIE,
JOS. H. HARPER, } Committee.
J. H. ELLISON,
G. O. FOSS,

The report was received and placed under discussion.

A vote of thanks was tendered Mr. Beckler for the kind proffer of the use of his offices for all meetings, and the offer was accepted.

The Secretary stated that he feared the treasury balance would not fully warrant the purchase of a suitable book case without being augmented through special assessment: that President Greene had kindly loaned him the use of a book case and chest of drawers for the Society's use, which would save this additional outlay for the present. Mr. Kelley moved that purchase of book case, as recommended in committee's report, be delayed until such time as the needs may more fully appear. Carried.

That portion of the committee's report relating to the appointment of a committee of four to expend $60 for the purchase of suitable books for the library was approved, and the chair requested to name such committee at his convenience.*

The Librarian reported that the *Transactions of the American Society of Civil Engineers*, contributed to the library by President Greene, embraced the years 1884 and 1885 complete, and that as the Society owned the volume for 1888 he would move that the Committee on Library, when named, be instructed to obtain the volumes for 1886 and 1887. Carried.

Mr. Keerl, the representative in the Board of Managers of the Association of Engineering Societies, read a communication of April 5, 1889, from Mr. Benezette Williams, Chairman of the Board, relative to an amendment to the Articles of Association, submitted by the Engineers' Club, of St. Louis, looking to "broadening the work of the Association and to a closer union of the Societies through the agency of the Association." He reported having voted in favor of the proposed amendment, which action was approved.

*** In compliance with the motion which was carried at the meeting of April 20, the chair has appointed the following members as the "Committee on Library:" Geo. K. Reeder, Frank A. Ross, Geo H. Robinson, L. O. Danse.—J. S. KEERL, Secretary.**

A telegram was read from Mr. A. B. Knight, of Butte, announcing his inability to be present to read his paper upon the "Law of the Apex," but promised an appearance at the next meeting.

Mr. L. O. Danse stated that while he had been unable to prepare the paper as assigned upon "The Construction of Modern Fireproof Buildings," he would give the meeting a talk upon the subject. He reviewed in detail the history of the efforts made to secure fireproof buildings, and stated the best practice as now recognized, sketching upon the blackboard the details of the various constructions as described. Discussion was had at the various stages of the lecture, and at its conclusion a vote of thanks was tendered Mr. Danse for the exceedingly instructive and entertaining manner in which he had presented this interesting subject, accompanied with the request that he would place his remarks in writing for publication.

Mr. Frank L. Sizer and others called the attention of the Society to the law passed by the last legislature relative to boiler inspection, pointing out several defects in the same, and suggested that the matter be brought up for discussion at the next meeting. The gentlemen were requested to address the Society upon the subject in a communication embodying their views that the matter could properly come before the Society for discussion.

The hour being late, the paper announced to have been read from Col. J. T. Dodge, upon "Ancient Roman Masonry," was placed upon the list for next meeting.

[*Adjourned.*] J. S. KEERL, Secretary.

MAY 18, 1889:—The regular monthly meeting was held at 8 P. M. at the offices of Mr. Beckler, Chief Engineer Montana Central Ry.

General B. H. Greene, President of the Society, presided. There were present Messrs. Haven, de Lacy, Beckler, Herron, Kelley, Foss, Danse, Wheeler, Sizer, Keerl and the following visitors: Hon. H. N. Blake, Chief Justice; Mr. Foster, of Butte; C. F. Pearis, and Wm. T. McFarland.

The inquiry was made whether any other than a written application for membership would be received. The chair ruled that no application would be permissible under the by-laws other than a written one embodying the information therein cited.

A communication was read from Mr. Geo. H. Robinson calling attention to the merits and demerits of the various provisions of a law recently enacted by the Montana legislature, for the regulation and management of steam boilers and steam engines, and creating the office of territorial boiler inspector and specifying the duties of such inspector. The communication reviewed the law very fully, section by section, and upon coming to Section 5 it recites: "which, among other things, provides for a hydrostatic test which shall exceed the working pressure allowed in the ratio of 100 to 75 or 25 per cent. It is quite probable that the framers of this law did not know that this practice was now obsolete and considered by the best authorities as injurious to the boilers that have been in actual use under steam pressure, and in some cases actually dangerous, as it is not a test of the working strength of the metal, for if the cold water test should permanently set any portion of the metal or strain it beyond its elastic limit, it leaves it in a very dangerous condition for future use with positively no means of detecting the damage done. Again, as the metal is cold, there is not a single member (in a steam boiler that has been in actual use) that has the same dimensions when cold as when heated up to its normal working temperature—about 325 degrees—consequently the strains along the riveted seams are all shearing, there being little if any frictional resistance or abrasion between the lapping sheets of metal along the riveted joints. As a rule, any boiler will leak under cold water pressure that is perfectly tight under steam pressure. The United States inspection of steam boilers provides, I believe, that static pressure is to be applied

only after the gauge shows 12 pounds pressure of steam. Would it not be just as reasonable for railroad bridge engineers to test their constructions under a radical difference of temperature and conditions of members that they would never in practice be called upon to resist, as for us to apply these radical differences in testing our steam boilers and creating strains that in actual practice the structure can never be called upon to withstand?

"Hydrostatic pressure is a valuable assistant before the boiler leaves the construction shops to ascertain if it is water tight, but should never be used cold for any other purpose, unless, indeed, it is sometimes used for testing boilers to rupture.

"The hammer test, with inside and outside inspection of the general condition, is the only method, I believe, recognized at the present time by boiler insurance companies as giving reliable data as to their condition and safety, assuming. of course, that the boiler has been properly constructed of suitable material."

Exception is taken to Section 8 in placing a horse-power qualification upon the abilities of persons operating steam machinery and boilers. The master mechanic, although he has entire charge of all machinery, etc., would appear not to come under the provisions of this act, which makes the oiler or runner the important man.

The communication was discussed by Messrs. Kelley, Danse and Keerl, and on motion was referred to a committee of five, to report at the regular meeting in July. The chair named as such committee Messrs. Robinson, Danse, Kelley, Keerl and Beckler.

Mr. Beckler read a paper by Col. J. T. Dodge upon "Ancient Roman Masonry," being a recital of the colonel's observations during a recent stay in Rome, and forwarded by him for presentation to the Society. The paper recited the details of construction of those grand old monuments to architectural and engineering skill—the Coliseum and Pantheon. The paper proved to be an exceedingly interesting one, and was the basis for an extended discusssion upon masonry in general. A vote of thanks was tendered Colonel Dodge for his entertaining paper, and Mr. Beckler was requested to convey the same, and to request of the colonel further papers upon engineering subjects of interest that he might encounter during his stay in Europe.

Mr. Keerl called the attention of the Society to several amendments in the bill prepared by the Society relating to town and village sites and plats, which were made in the Legislature, particularly to the clause providing that all plats should be approved by the board of county commissioners before filing. Owing to the long intervals between the meetings of the board, the proprietors of platted property were unable to file their plats and place it on the market as soon as they desired, and the Society was being blamed for introducing so unreasonable a provision in the bill, whereas the objectionable clause was an amendment inserted in the bill in the Legislature.

[*Adjourned.*] J S. KEERL, Secretary.

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DUTY TRIALS OF PUMPING ENGINES—A PLEA FOR A STANDARD METHOD OF CONDUCTING THEM.

By George H. Barrus, Member of the Boston Society of Civil Engineers.

[Read January 16, 1889.]

(1.) There is no class of steam engines whose economy is tested so frequent as that form of steam pumping engine which is used for supplying water works. Nearly every engine of this kind which is built goes into the hands of the purchasers with the builders' guarantee that it shall do its work in accordance with a certain specified duty. Every engine thus guaranteed is generally made the subject of a duty test before the builder receives the full payment of his bill. The test is conducted either by a representative of the builder or by the civil engineer under whose direction the water works have been constructed, or by the superintendent of the pumping station or by his engineer, or, in rare instances, by an expert or a board of experts appointed by the purchaser of the engine or by a board representing both parties. When the contract between the builder and the purchaser has been framed with a suitable degree of foresight, which rarely happens, the method of conducting and working out the result of the test is laid down as a part of the contract, and the person conducting the test has simply to follow the terms which it specifies. In the majority of cases the purchaser knows so little about the subject of duty trials that he cannot, on his part, exercise much foresight in the framing of the contract, and the matter of the stipulations as to the duty test are left to the builder. The builder's interest is to express the guarantee in such general language that, in case of dispute as to the result, he may be secure from failure. It follows that in most duty trials the person who conducts the test is neither governed nor hampered by distinct specifications of the contract, and he may employ any method which suits his individual whim or judgment. There is no standard method which has been established by any common consent, and the few cases which may be used as precedents are not applicable to the individual requirements of special engines.

It is not surprising, under these circumstances, that a great variety of practice exists as to duty tests, and this variety covers the whole

field, beginning with the definition of the term "duty," which determines what are the main quantities which it is the object of the test to ascertain, and ending with the manner of making the observations by which the necessary data are obtained. An examination of various pumping engine contracts, and the reports of tests made under them, will show a state of affairs something like the following: One person holds that the term "duty" means the number of pounds of water elevated one foot by 100 pounds of coal, the water being actually measured. Another holds that it is the number of pounds of water elevated one foot, plus the quantity of work which is equivalent to the friction of the force main, using the same unit of 100 pounds of coal. Another holds that it is the quantity of water, as determined by plunger displacement, elevated one foot, either with or without allowance for friction of force main, the basis being 100 pounds of coal. Still another claims that it is the number of foot-pounds of work done as measured by the indicator diagram taken from the pump end of the engine, on the 100 pounds basis; and others adopt various allowances in the matter of slip or loss of action and friction of suction pipe and pump valves; while still others base the duty on the quantity of combustible instead of the quantity of coal consumed. One class of tests is based on the stipulation of 100 pounds of coal, assuming that the coal gives a certain evaporative performance, in which case the duty is practically reduced to the work done by a given quantity of steam. Sometimes this quantity is expressed as water pumped into the boiler by the feed pump, irrespective of the quality of the steam into which it is generated, and without taking into account the water of condensation returned independently from the jackets of the engine or from other sources. Sometimes it is expressed as "water from and at 212 degrees," in which case the temperature of the feed water enters the problem. Sometimes the quantity of steam on which the duty is based is that of dry steam or of steam containing not over a stipulated percentage of moisture, and sometimes it is the steam used by the steam cylinders of the pumping engine, apart from that used by any of the accessories of the engine, such as jackets, air pump of condenser, feed pump of jacket water and main feed pipe of boiler.

It may be held, by one unfamiliar with the construction of pumping engines and the manner of conducting duty tests, or by one who is conversant only with the general subject of steam engineering, that the variations in the results of duty tests which creep in on account of the various practices here indicated, are not sufficiently large to make the subject one of much consequence to any but specialists. The only thing needed to show that the matter thus viewed, instead of being of little consequence, is one of the highest importance, is a full knowledge of the extent to which these differences of practice affect the results. The friction of a force main of suitable size and of average length often increases the work required to be done in pumping the water as much as 10 per cent. The difference between the quantity of water delivered and that measured by plunger displacement is frequently 5 per cent. The percentage of ash in coal never falls below 5 per cent., and sometimes is as high as 15 per cent., or even 20 per cent. The percentage of moisture in

steam is often as much as 3 per cent., and in some instances a much greater quantity. The quantity of steam condensed in the jackets is generally 5 per cent, and sometimes 10 per cent. of the whole quantity used by the plant. The steam used by the donkey feed pump under the most favorable circumstances amounts to from 3 to 5 per cent. of that used by the main engine. When an independent air pump is employed the consumption of steam is increased some 10 per cent. by the use of this apparatus. The difference in economy produced by an evaporation from and at 212 degrees and the observed evaporation when the feed water is not heated above 100 degrees is not less than 15 per cent.

A wide range of results may thus be secured in a given trial according to the meaning which is applied to the term "duty," and the method employed in making the calculations. In a case of dispute of which the writer has knowledge, a variation in the number of foot-pounds of work done by 100 pounds of coal amounting to the excessive figure of 56,000,000 foot-pounds occurred between the method pursued by a responsible builder and that pursued by the purchaser, though based on the same contract. Here is an illustration showing that the conflict of opinion which may arise on account of the manner of conducting and figuring a duty trial, is one which may assume grave proportions.

2. The essential object of a pumping engine test is to determine the engine's economy, and the economy according to the popular idea is measured by the amount of duty realized. The term "duty," however, with its elastic meaning, furnishes no guide whatever as to the real economy, seeing that the duty of the same engine computed from the same data by different individuals may vary over a wide range. In view of this fact it is manifest that some standard method of expressing the economy of pumping engines and of determining the data and computing the result should be determined upon and followed. Such a standard will tend to secure five objects.

First. It will enable one engine to be compared with another and its relative economy shown. This object is the one which has the widest application.

Second. It will aid the builder, who will learn how his machine compares with some competing type.

Third. It will aid the purchaser, who usually has no technical knowledge of such matters, for by its means he may obtain the true economy of different engines, irrespective of the unwarranted claims of those who have engines for sale.

Fourth. It will aid the engineer, who, from his study of the economy of different types of engines, has an interest in obtaining data which will enable him to make improvements in the design, construction and arrangement of an engine which is inefficient.

Fifth. An authoritative standard having been established, it will be sufficient for the purposes of the contract between the builder and the purchaser, to stipulate that the engine shall realize the economy guaranteed simply "in accordance with the method of conducting duty trials determined upon by" the authority named. No misunderstanding can then arise. Many, if not all, sources of dispute will be removed when the stipulations of a contract are based upon a standard method. If th

contract is not thus based and there is any doubt in the mind of the person conducting the test or any dispute between him and the builder, the matter can be more easily settled when there is a standard method to which reference can be made, as an accepted authority, than it can be without such a method.

3. The standard method of conducting duty trials should be framed in such a manner as to be applicable to every pumping engine, or at least to a large majority of such engines. Unless this end can be reached, the standard will fail to realize one of its essential objects, that is, it will not serve to put the economic results obtained by different engines on the same basis for comparison. In order that this may be done, it is apparent, first, that the results must be referred to some fixed unit. From what has already been said, it seems that quite as much confusion arises from the variable nature of the unit upon which the results are based, as from the want of uniformity in the manner of determining the results. The unit "100 pounds of coal" is exceedingly variable. In the eastern states, it may be Cumberland coal, which evaporates 12 pounds of water from and at 212 degrees per pound of combustible, or anthracite coal, which evaporates not more than 11 pounds. In the middle of the western states, it may be Pittsburgh, Indiana or Ohio coal, neither of which yields so high an evaporation as the lower figures named. In a given locality, too, there is much variation from time to time in the quality and evaporative value of coal of the same class. The unit "100 pounds of coal assuming an evaporation of 10 pounds of water per pound of coal" is also variable, according as the temperature of the feed water and pressure of the steam are taken into account, and according as allowances are made for moisture in the steam and for steam used by the jackets, feed pump and other accessories.

The common practice in the general lines of steam engineering is in the direction of discarding the coal measure of economy altogether, and expressing the performance of an engine in terms of the quantity of steam consumed. The reason for this practice is the well-known fact already noted, that the quantity of coal burned depends to some extent upon the evaporative value of the coal and the efficiency of the boiler, independent of the economy of the engine itself. A given engine may consume, for example, 2.5 pounds of coal per horse power per hour when supplied with steam from one boiler, and only 2.0 pounds when supplied from another which is more economical. It would be absurd to hold that the economy of the engine was 25 per cent. greater in one case than in the other. The economy would be equal because of the equality in the amounts of steam consumed. The engine is quite independent of the boiler, except in rare instances, so far as questions of economy are concerned, and nothing is gained by treating them as one and expressing the economy in terms of the coal measure.

The same considerations which make the coal unit unfit for a basis of economy for engines in general prevent it from being applied to steam pumping engines. It matters little whether the mechanism of the engine operates machinery for pumping water or for doing other kinds of work. It is in all cases a *steam engine* and the principles which are followed in order to secure economy are the same in one place as in another.

The desirability of employing some other unit than "100 pounds of coal" in measuring the duty of a pumping engine is recognized in cases, which are of frequent occurrence, where the contract provides that the boiler shall evaporate a certain amount of water per pound of coal. In reality, the unit in those cases is a certain number of pounds of steam used by the engine. The steam unit is free from the objection urged against the coal measure. It is much better adapted for the purposes in view than the coal unit, since it is the steam which enters the cylinder and does the work, and not the coal. For some purposes and in some cases the steam unit furnishes a perfectly satisfactory measure of the performance of an engine. For others it does not. Suppose we compare two pumping engines, one of which is a single cylinder condensing engine and the other a compound condensing engine, and both are provided with the independent form of air pump which exhausts into the atmosphere. Suppose also the same boiler pressure is carried in both. The relative duty and economy of these two engines would be expressed near enough for all ordinary work if computed on the basis of the number of foot pounds of work done by say 1,000 pounds of dry steam. Suppose, now, that steam is supplied by boilers which give the same evaporative efficiency, and suppose a feed-water heater is added to the plant of one, arranged so as to utilize the heat wasted by the discharge of the exhaust steam from the independent air pump. This change will, according to reliable experiments, enable the water to be supplied at a temperature of 200 degrees, where before its temperature was, say, 100 degrees, and it will reduce the quantity of coal required to make a given quantity of steam, in the boiler referred to, about 10 per cent. There is no change in the relative quantity of steam used by the two engines, and the duty figured upon the unit of 1,000 pounds of dry steam remains the same in both cases. If the comparison of the two engines, under the changed conditions, is now made, the fact cannot be ignored that something must be done with the 10 per cent. saving of coal which one engine has realized, and no one who takes into account the financial aspect of the question will fail to disregard the bearing which this has upon the results. A similar illustration may be given in the case of two engines, one a condensing engine and one a non-condensing engine, fitted with a heater. In these examples resort must be had either to the coal unit of measurement or to some measurement which allows for the heat returned with the feed water. The steam unit is thus limited in its application, and, like the coal unit, must be considered unfit for the purposes of a standard.

We may readily find a unit, which is satisfactory for all purposes and conditions, if we remember that a pumping engine is a heat engine, and that heat is the agent which we really have to supply in order to operate the engine. The quantity of heat used by the engine is independent of the kind of coal or of the efficiency with which steam is generated in the boiler. It varies, however, with the quantity of steam consumed, increasing when that is increased and becoming less when that is reduced; and it varies with the quantity of heat returned to the boiler, being reduced when that quantity is increased and being increased when that quantity is diminished. It takes account also of the variations of heat

due to different boiler pressures. These applications cover the whole field, and the heat measure of economy may be considered the only true basis upon which to express the performance of a pumping engine.

The use of a certain quantity of heat as a unit upon which to calculate the duty of a pumping engine does not involve a radical departure from the nominal unit of 100 pounds of coal, which is in common use. The unit may be selected so as to correspond to the heat produced by the combustion of 100 pounds of coal, where the coal is of good quality and the conditions are favorable: and if this be done the results will not depart from the general ideas which have been formed as to the number of foot pounds of work which 100 pounds of coal can be expected to give. If we assume an evaporation of 11.25 pounds of water from and at 212 degrees per pound of coal (which is a good performance for a boiler using Cumberland bituminous coal), the quantity of heat which one pound of coal supplies is 11.25 by 966 equals 10,867.5 B. T. U. This quantity is a little in excess of the round figure of 10,000. The present unit of 100 lbs. of coal, supposing the coal to be of a fair grade, may be represented then in round numbers by 1,000,000 thermal units of heat. Reduced to exact figures, this quantity of heat is the same as that supplied by 100 pounds of coal, assuming an evaporation of 10,352 pounds of water from and at 212 degrees per pound of coal. This evaporation of 10 352 pounds can be obtained by the best grade of anthracite coal and by almost any grade of Cumberland bituminous coal, though it is somewhat beyond the range of most of the bituminous coals of the western states. Considering, therefore, that 1,000,000 thermal units of heat used by a pumping engine may be employed for a unit upon which to calculate the duty, without materially changing the result from that obtained if calculated upon the basis of 100 pounds of good coal, and considering, farther, that this unit takes into account the quantity of steam used by the engine, and that portion of the rejected heat of the engine which is utilized in warming the feed water, there are reasons of the strongest character for adopting this unit for the purposes of a standard method of conducting duty trials. This view of the matter is supported by the opinion and latest practice of the experts of Europe, whose reports of tests base the performance of steam engines, not solely upon the feed water consumption, but upon the number of thermal units of heat consumed.

4. Starting with a thermal unit basis of computing duty, it is apparent that one of the principal elements in the computation is the quantity of heat supplied to the engine. To determine this quantity, the dryness of the steam must be known. Allowance will therefore be made at the outset for any moisture or superheat which the steam contains, and this matter is at once settled.

As to other allowances, there seems to be no good reason why the steam used by any of the accessory parts of the engine, that is, for the donkey feed pump, the steam jackets, the independent air pumps, and any other apparatus which is necessary to the operation of the engine, should be deducted from that used by the plant as a whole. It is true that an engine which is constructed and operated in accordance with the most approved principles and which in itself is economical, may appea

quite the reverse if no allowance for this steam is made. The accessory apparatus may cause waste which will offset all the economy due to the excellence of the main part of the engine. Some may say, therefore, that unless allowance is made for the steam used by the accessory apparatus, confusion may arise as to the economy of the engine itself. It is to be observed, however, that the accessory apparatus is a necessary part of the equipment of the engine, and that it should be constructed in a manner to secure economy the same as the engine itself. Besides, it uses heat which must be furnished from the source of supply, and the supply of this heat is a necessary element of cost in the running of the engine. No reasonable objection to computing the duty from the heat used by the whole plant can be urged, when the data of the test are taken with such completeness, that the quantity of steam used by the engine proper and by each accessory part of the plant is determined separately, so as to furnish incidental knowledge of the economy of each.

The standard basis of 1,000,000 thermal units is to be applied then, not only to the heat consumed by the engine proper but to that consumed by all accessory parts of the engine, such as steam-pumps (including donkey-pumps), and jackets and all apparatus necessary to the operation of the engine. Furthermore, the computation is to be made upon the whole heat thus consumed, not only in cases where a contractor furnishes both the boiler and engine, but in cases also where he furnishes simply the engine. No change is to be made in the method pursued because the donkey-pump (assuming this to be a steam-pump) may be considered as an accessory to the boiler. The heat supplied to the donkey-pump is to be included in all cases in the total quantity, but the contractor may specify, if he desires, the kind of feeding apparatus which shall be used, provided he does not supply it as a part of the engine.

5. Having determined upon an appropriate unit upon which to base the computation of "duty," we may now consider what shall be embodied in the expression for quantity of work done. This, too, must apply, so far as may be, to every case. The work consists of two factors, the number of pounds of water pumped, and the number of feet in elevation to which the water is raised. The determination of the first named factor is the only one which involves any difficulty. There are two methods which may be employed. One, the use of either the standpipe or the reservoir for the purpose of a measuring tank, the other the use of a weir. The first is the simpler method, but it is not altogether satisfactory. It has the serious objection that it requires the shutting off of the supply of water to the service main while the test is going on, and for such additional time as is necessary to determine the allowance for leakage from the standpipe or reservoir. The use of the standpipe for this purpose is objectionable, because the comparatively small quantity which can be measured at one filling makes the determination an approximate one. On the other hand, where the water is measured in the reservoir, which is usually of large area, a large quantity must be pumped to make an accurate test, but this is out of the question, owing to the limited number of hours during which it is feasible to have the water shut off. These

must both be regarded as rough means of measurement, and hardly adapted to the object in view. The second method, viz., that of weir measurement, can be employed to advantage only in cases where the reservoir system of water-works is used. This system is not uncommon, but it is by no means universal, and this method becomes objectionable because of limited application. It has the further objection that the construction of a suitable weir involves a large additional expense to the cost of the apparatus, and to the cost of making the test as well, and that the observers who have the measurements in charge must be specially trained to this class of work. The difficulties which thus surround the determination of the quantity of water actually discharged, are such that it appears impracticable to use any form of direct measurement for a standard.

The only means by which the water can be measured which is of ready application is the indirect but simple method in common use, furnished by computing the plunger displacement and using the pump itself as a meter. This method has the merit of universal application, and the objections which may be raised against it are of less weight than those pertaining to the methods thus far considered. Owing to leakage of plunger and valves, imperfect action of the valves and incomplete filling due to the presence of air mingled with the water, these three quantities constituting what is termed "slip," the actual discharge from the pump is less than the calculated discharge based on this method of measurement. Two pumps might give the same plunger displacements, but, owing to variations in the losses noted, quite different quantities of water actually discharged. It is important to the purchaser of the pump, if to no one else, that the duty trial should take into account these losses. The purchaser's interest centres in the quantity of water pumped, and not in the number of volumes swept over by the plunger, and this interest cannot be ignored. So far as known, there is no means of correcting for the various losses noted, which possesses scientific accuracy, but it is believed that for the practical object in view in fixing a standard, corrections may be applied which will, in a reasonable manner, answer the requirements of modern pumping engines as now manufactured in the United States.

The fact of the presence or absence of leakage by the piston or plunger can be ascertained by blocking the engine, removing the cylinder head, and subjecting the plunger to the full water pressure, thus allowing the leakage to appear to view. If a sufficient amount of leakage is found to make a correction advisable, the water which leaks may be collected and measured, and the correction applied accordingly.

It may be held that leakage of the plunger at rest may take place at a different rate from leakage in motion, and, therefore, the results of the trial may be misleading. It may be urged also that, owing to a difference of pressure when the pump is at rest, the results will be changed from what they would be under the working conditions of pressure. These objections to the proposed trial are worthy of consideration, but it must be remembered that the object of the trial is not to make a scientific determination of the amount of leakage, but rather to determine its approximate rate and apply a correction which may, in some measure at least, protect the purchaser's interest.

There should be no leakage of valves, unless some are defective. Being constructed of rubber, there is reason to expect that they will be practically tight when seated. Both the suction valves and the discharge valves can readily be tested, the former by observing whether they will hold water, and the latter by observing whether water passes through them into either end of the cylinder when they are under pressure. When leakage is found, the defective valves should be replaced by others in good condition before the duty trial is made.

There is no method known whereby the loss due to the return of the water through the valves at the end of the stroke, while the plunger is reversing and the valves are seating, or "loss of action" as it may be called, can readily be measured, and no data exist on this subject by means of which its quantity can be computed. If allowance for this loss is made it will therefore be mere guess work. Considering that modern pump valves generally have a small lift, it would seem that the loss from this cause ought to be small at best, and if it varies in different pumps, as no doubt it does, the variation would also be small and perhaps unimportant. With this view of the matter, no large error can be made in a comparison of different engines (which is the main thing in view) by disregarding loss of action by the valves altogether.

The effect which incomplete filling due to the introduction of air has upon the quantity of water discharged, if it is worth noticing at all, may be shown by the form of the indicator diagram taken from the pump cylinder. A rectangular diagram is sufficient indication of the absence of air. A diagram in which the attainment of the full pressure is delayed until some time after the beginning of the stroke, indicates the presence of air. When this condition of things is found, the correction to apply is the proportion of the displacement which has been covered at the point where the full pressure is attained, determined by measurement from the diagram.

In view of these considerations, it seems that the best standard for the quantity of water pumped is that determined from plunger displacement, corrected for leakage of the plunger, and for loss from the introduction of air into the pump, should it be found that these losses exist. It is presumed that the pump is operated with every by-pass or connection between the suction and force mains closed, so that no water once pumped can thus pass back into the suction main.

It is quite generally recognized that in computing the quantity of work done, no allowance should be made for friction of the water in passing through the passages and valves in the pump, while, on the contrary, allowance should be made for the friction of the force and suction mains. The ground taken for this practice is the fact that the efficiency of the engine should not be made dependent upon any condition foreign to itself. The builder of the engine should not be held responsible for the size, arrangement, length or condition of the pipes which lead the water to the pump and conduct it away. His responsibility should begin at the point where the water enters the pump and end where the water leaves the pump; and consequently he should bear simply the lost work due to friction of the water passing through. The purchaser should guard his interest in the matter by providing pipes of such capacity an

arrangement as to reduce their friction to a minimum, and he should give special attention to cases where pipes are furnished as a part of the contract for the engine.

This practice as to allowance for friction appears to be the proper one for the purposes of a standard method. To carry it into effect, the data to be determined are the indication of a pressure gauge attached to the force main, that of a vacuum gauge attached to the suction main (or pressure gauge if the inlet is under a head) and the vertical distance between the centres of the two gauges.

We have now, for the standard mode of expressing the amount of work done, the weight of water computed from plunger displacement corrected for leakage and the presence of air as pointed out, elevated to a height corresponding to the pressure shown by a gauge attached to the force main plus the head corresponding to the vacuum shown by a gauge attached to the suction main (or minus this head if the gauge shows pressure instead of vacuum) plus the vertical distance between the centres of two gauges, no allowance being made for friction of the water passing through the passages and valves in the pump.

6. In accordance with the views of the subject thus laid down the duty of all engines would be expressed by the following formula:

$$\text{Duty} = \frac{\text{Ft. lbs. work done}}{\text{The units of heat consumed}} \times 1{,}000{,}000$$

$$= \frac{[CVwN - L] \times [H + s + h]\ 1{,}000{,}000}{\text{The units of heat consumed}} \text{ in which}$$

V = Volume of piston displacement, one stroke, cubic feet.

w = Weight of one cubic foot of water.

N = Number of strokes during trial.

H = Head in feet corresponding to indication of pressure gauge on force main.

h = Head in feet corresponding to indication of vacuum gauge on suction main.

[This is a minus quantity where there is a head of water on the suction main and pressure gauge is used.]

s = Vertical distance in feet between the centres of two gauges.

L = Total leakage of plungers during trial estimated from results of leakage test with pump at rest.

C = Correction for air admitted into the pump = proportion of the stroke during which the pump is subjected to the full discharge pressure, measured from the indicator diagram.

Thr. units of heat consumed = weight of water supplied to boiler by main feed pump × total heat of steam of boiler pressure above temperature of main feed water, plus weight of water supplied by jacket pump × total heat of steam of boiler pressure above temperature of jacket water, plus weight of any other water supplied × total heat above its temperature of supply. The total heat of the steam is corrected for the moisture or superheat which the steam may contain. For moisture, the correction is subtracted, and is found by multiplying the latent heat of the steam by the percentage of moisture, and dividing the product by 100. For superheat, the correction is added, and is found by multiplying the number of degrees by superheating (*i. e.* the excess of the temperature of

the steam above the normal temperature of saturated steam) by 0.48. No allowance is made for heat added to the feed water, which is derived from any source, except the engine or some accessory of the engine. Heat added to the water by the use of a flue heater at the boiler is not to be deducted. Should heat be abstracted from the flue by means of a re-heater connected with the intermediate receiver of the engine, this heat must be included in the total quantity supplied by the boiler.

The following examples are given to illustrate the method of computation. The figures are not obtained from tests actually made, but they correspond in round numbers with tho e which were so obtained.

First Case.—Jacketed compound fly-wheel engine. Jacket water returned to boiler by gravity. Jet condenser, with air pump, operated by main engine. Feed pump driven by main engine supplied with water from hot well, which receives drip from intermediate receiver. No heaters.

1.	Boiler pressure by gauge	100	Lbs.
2.	Capacity of pump displacement one stroke (V)	12.5	cubic feet.
3.	Number of strokes during trial (N)	140,000	
4.	Pressure by gauge on force main	80	lbs.
5.	Vacuum by gauge on suction main	4.8	in.
6.	Vertical distance between gauges (s)	10	ft.
7.	Temperature of water in pump well	60	deg.
8.	Leakage of pump determined by trial at rest (L)	546,000	lbs.
9.	Kind of pump diagram	Rectangular (or C = unity)	
10.	Weight of water supplied by feed pump	188,000	lbs.
11.	" " from jackets	9,000	"
12.	Temperature of main feed water	100	deg.
13.	" jacket water	290	"
14.	Percentage of moisture in steam	2.5	per cent.

Additional Data Based on the Above.

15.	Weight of one cubic foot of water at 60 deg. (w)	62.4	lbs.
16.	Head corresponding to pressure in force main $\dfrac{(80 \times 144)}{62.4} = H$	184.6	ft.
17.	Head corresponding to vacuum in suction main $(4.8 \times 1.13) = h$	5.4	ft.
18.	Total heat of one pound of dry steam at 100 lbs. gauge pressure reckoned from 0 deg. Fahr	1,216.5	th. un.
19.	Total heat of one pound of steam at 100 lbs. gauge pressure containing 2.5 per cent. moisture	1,194.6	"
20.	Total heat of one pound of steam at 100 lbs. gauge pressure containing 2½ per cent. of moisture reckoned from temperature of main feed water (100 deg. F.)	1,094.6	"
21.	Total heat of one pound of steam at 100 lbs. gauge pressure containing 2½ per cent. of moisture reckoned from temperature of jacket water (290 deg. F.)	902.2	"
22.	Heat consumed by engine $188{,}000 \times 1{,}094.6 + 9{,}000 \times 902.2 =$	213,904,600	"

Applying these quantities in accordance with the duty formula, we have

$$\text{Duty} = \frac{\left[(\overset{N}{140{,}000} \times \overset{V}{12.5} \times \overset{w}{62.4}) - \overset{L}{546{,}000}\right] \times (\overset{H}{184.6} + \overset{h}{5.4} + \overset{s}{10}) \times 1{,}000{,}000.}{213{,}904{,}600.}$$

$$= \frac{21{,}730{,}800{,}000 \times 1{,}000{,}000}{213{,}904{,}600.} = 101{,}593{,}268 \text{ ft. lbs.}$$

Second Case.—Jacketed Compound Direct Acting Duplex Engine. Jet Condenser. Independent Air Pump, which exhausts through a heater Feed water supplied by an independent donkey pump, which exhaust-

through the heater. Jacket water returned to boiler without passing through heater.

1. Boiler pressure by gauge .... 120. lbs.
2. Capacity of pump displacement one stroke (V).......... 3.75 cubic feet.
3. Number of strokes during trial (N).......... 76,000.
4. Pressure by gauge on force main .... 100. lbs.
5. Vacuum by gauge on suction main.......... 9.3 in.
6. Vertical distance between gauges (s).......... 8. feet.
7. Temperature of water in pump well .... 80. degrees.
8. Leakage of pump determined by trial at rest (L).......... 354,540. lbs.
9. Kind of pump diagram .... Rectangular (or C = unity)
10. Weight of water supplied by feed pump.......... 56,000. lbs.
11. " " " " " jackets .... 6,400. lbs.
12. Temperature of main feed water.......... 215. degrees.
13. " " jacket water.......... 280. degrees.
14. Percentage of moisture in steam.......... 3. per cent.

Additional data based on the above.

15. Weight of one cub. ft. of water at 80 deg (w).......... 62.2 lbs.
16. Head corresponding to pressure in force main $\dfrac{(100 \times 144)}{62.2} = (H)$ 231.5 ft.
17. Head corresponding to vacuum in suction main $(9.3 \times 1.13) = (h)$.......... 10.5 ft.
18. Total heat of one pound of dry steam at 120 lbs. gauge pressure reckoned from 0 deg. Fah.......... 1,220.2 th. un.
19. Total heat of one pound of steam at 120 lbs. gauge pressure containing 3 per cent. of moisture.......... 1,194.2 th. un.
20. Total heat of one pound of steam at 120 lbs. gauge pressure containing 3 per cent. of moisture reckoned from temperature of main feed water (215 deg. F.).......... 978.3 th. un.
21. Total heat of one pound of steam at 120 lbs. gauge pressure containing 3 per cent. of moisture reckoned from temperature jacket water (280 deg. F.).......... 912.2 th. un.
22. Heat consumed by engine..........$56,000 \times 978.3 + 6,400 \times 912.2$ = 60,622,880 th. un.

Applying these quantities to the formula, we have:

$$\text{Duty} = \frac{[(76,000 \times 3.75 \times 62.2) - 354,540] \times (231.5 + 8 + 10.5) \times 1,000,000}{60,622,880}$$

$$= \frac{4,343,115,000 \times 1,000,000}{60,622,880} = 71,641,374 \text{ ft.-lbs.}$$

Third Case.—Jacketed Fly-wheel Compound Engine. Intermediate receiver fitted with reheater supplied with lime steam. Main steam pipe provided with separator. Water drained from jackets, reheater, and separator into a closed tank under boiler pressure, from which the water is supplied to the boiler by a small steam pump. Jet condenser, fitted with independent air pump, which exhausts through a heater to the atmosphere. Main supply of feed water drawn from hot well and fed to boiler by injector, discharging through the heater. The main feed water and the auxiliary supply enter the same feed pipe just before its connection to the boiler. The auxiliary pump exhausts through the heater. Number of plungers, 2; diameter of each plunger, 19 inches; length of each stroke, 36 inches; diameter of each piston rod, $3\frac{1}{2}$ inches.

1. Boiler pressure by gauge.......... 120 lbs.
2. Capacity of pump displacement, one stroke each plunger $= \dfrac{\text{area } 19 - 1\text{-}2 \text{ area } 3\ 1\text{-}2}{144} \times 3 (V)$.......... 5.806 cub. ft.
3. Number of strokes of one plunger during trial (N)..........280,000
4. Pressure by gauge on force main.......... 80 lbs.
5. Vacuum on gauge by return main.......... 4.8 in.
6. Vertical distance between centres of gauges (s).......... 10 ft.
7. Temperature of water in pump well.......... 60 deg.
8. Leakage of plunger determined by trial at rest (L)..........546,000 lbs.
9. Correction for admission of air into the pump (C).......... .95
10. Weight of water supplied by main feed pump..........188,000 lbs.
11. Weight of water supplied by auxiliary pump from the jacket, reheater and separator tank.......... 12,000 lbs.

12. Weight of water discharged from jackets	7,000 lbs.
13. " " " reheater	2,000 "
14. " " " separator	3,000 "
15. Temperature of water supplied from hot well to injector	110 deg.
16. Temperature of water discharged from injector and entering heater	180 "
17. Temperature of feed water leaving heater	215 "
18. " jacker water previous to entrance to tank	290 "
19. " reheater " " "	300 "
20. " separator " " "	340 "
21. Percentage of moisture in the steam leaving separator according to calorimeter test	0.5 per cent.
22. Weight of one cubic foot of water at 60 degrees (w)	62.4 lbs.
23. Head corresponding to pressure in force main $\frac{80 \times 144}{62.4} = (H)$.	184.6 ft.
24. Head corresponding to vacuum in suction main, $4.8 \times 1.13 = (h)$	5.4 ft.
25. Total heat of one pound dry steam at 120 pounds gauge, pressure reckoned from 0 deg. Fahr	1,220.2 th. un.
26. Total heat of one pound of steam at 120 lbs. gauge pressure, containing 0.5 per cent. of moisture = 1220.2 — [.005 × 867.5 (latent heat)]	1,215.9 "
27. Total heat of one pound of steam at 120 lbs. gauge pressure, containing 0.5 per cent. of moisture, reckoned from temperature of main feed water, corrected for heat derived from injector = 1215.9 — [110 + (215.9 — 180.6)] = 1215.9 — 145.3	1,070.6 "
28. Total heat of one pound of steam at 120 lbs. gauge pressure, containing 0.5 per cent. of moisture reckoned from temperature of jacket water (290 deg.) = 1215.9 — 292	923.9 "
29. Total heat of one pound of steam at 120 lbs. gauge pressure, containing 0.5 per cent. of moisture reckoned from temperature of reheater water (300) deg. = 1215.9 — 302.1	913.8 "
30. Heat lost by cooling of one pound of the separator water from its temperature in the boiler (349.9 deg.) to its temperature of discharge to tank (340 deg.) = 352.6 — 342.7	9.9 "
31. Heat consumed by engine = (188,000 × 1070.6) + (7,000 × 923.9) + (2,000 × 913.8) + (3,000 × 9.9)	209,597,400 th. un.

Applying these quantities in accordance with the duty formula, we have:

Duty =

$$\frac{\left[(\overset{C}{.95} \times \overset{V}{5.806} \times \overset{w}{62.4} \times \overset{N}{280.000}) \times (\overset{H}{184.6} + \overset{h}{5.4} + \overset{s}{10})\right] \times 1,000,000}{209,597,400.} =$$

$$\frac{19,274,062,080 \times 1,000,000}{209,597,400.} = 91,957,544.$$

7. The adoption of the method thus pointed out for expressing the duty of the engine does not stand in the way of suitable treatment of the boiler. This may be guaranteed independently. It may furnish, say, 1,000,000 th. un. of heat to the engine with a consumption of a stipulated number of pounds of a given kind of coal. The same end may be reached by guaranteeing the evaporation of a certain number of pounds of water from and at 212 degrees per pound of the coal named, but the form of expression first noted is preferable, since the duty of the engine referred to the heretofore recognized unit of 100 pounds of coal, can then be readily determined by dividing the duty for 1,000,000 th. un. by the number of pounds of coal required, and multiplying the result by 100. There could thus be two guarantees in case the contractor furnished the whole plant, one applying to the engine and one to the boiler.

The adoption of the proposed method of displacement measure of the quantity of water pumped does not stand in the way of actual measurement by a weir or by other means where opportunity presents itself for such work. No objection can be raised to a contract which requires a

weir test to be made, for the more this class of data is obtained, the better; but this test can be regarded as furnishing supplementary data, the main results being referred to the standard of displacement measure.

8. To cover the foregoing requirements in the framing of a contract, the guarantee as to the performance of a complete plant may be expressed in the following terms: "The engine shall perform a duty equivalent to not less than (*A*) foot-pounds of work for each one million thermic units of heat consumed, and the difference between the actual delivery by weir measurement and that calculated from plunger displacement shall not exceed (*B*) per cent. Furthermore, the boiler shall supply 1,000,000 th. un. of heat to the engine on a consumption of (*C*) pounds of (*D*) coal. The duty trial is to be conducted and the results computed in accordance with the standard method of conducting duty trials, determined upon by (the authority named)." If one contractor furnishes the engine and another the boiler, separate guarantees will be made, the individual requirements being the same as in the case of the complete plant.

9. It may be urged against the adoption of a thermal unit standard for expressing the duty of pumping engines that it will add complication to the process of making the test, and be objectionable on this account. A little examination will show that this objection has no weight, and the extra labor and complication is so small that there is but slight ground for raising it. The thermal unit method will undoubtedly make the test more complicated than the simple determination of the weight of coal burned and number of foot pounds of work done. So does the determination of the duty on the basis of the weight of steam used, and the extra labor which this kind of test involves is already expended in many cases. When the steam basis is used, the weight of the main supply of feed water and that of every auxiliary supply is required. No more weights than these are needed on the thermal unit test, so that in respect to weighing the two methods are alike. The complications that the thermal unit method introduces are those due to the taking of the temperatures of each supply of feed water. But it should be remembered that these temperatures are required when the steam unit is from and at 212 degrees, and furthermore the temperatures are always taken when the full data regarding the performance of the engine, as frequently occurs, are determined. Some complication arises on account of the necessity of taking some feed-water temperatures at a different time from that of taking the weights, such as that of the main supply when drawn from the hot well of the condenser. It is not often practicable to weigh the hot well water, and the test of the quantity of feed water consumed must be made with cold water from the service main. The test of the feed water consumption and the evaporative efficiency of the boiler would naturally be made on one occasion, and the working temperature of the various sources of feed-water supply would be made the subject of independent trial. It is thus seen that the thermal unit method has no complications that stand in the way of its ready adoption.

10. Having now determined upon the units of measurement and the character of the result which is sought, we may now proceed to formulate a standard method of conducting the test and obtaining the data.

STANDARD METHOD OF CONDUCTING DUTY TRIALS.

1. It is presumed at the outset that the engine is in thorough order in every part, having been in operation a sufficient length of time since its erection to secure easy and proper working. If this has not been done, and especially if the plunger has been recently packed, or its packing newly readjusted, the engine is worked for a run of at least 12 hours continuous service in preparation for the test.

2. The plant is subjected to a preliminary run under the conditions determined upon for the test, for a period of at least 3 hours, so as to find the temperature of the feed water (or the several temperatures, if there is more than one supply), for use in the calculation of the duty. During this run the observations are made every 15 minutes and the results averaged.

When the feed water is all supplied by one feeding instrument, the temperature to be found is that of the water in the feed pipe near the point where it enters the boiler. If the water is fed by an injector, this temperature is to be corrected for the heat added to the water by the injector, and for this purpose the temperatures of the water entering and of that leaving the injector are observed. If the water does not pass through a heater on its way to the boiler (that is, that form of heater which depends upon the rejected heat of the engine, such as that contained in the exhaust steam either of the main cylinders or of the auxiliary pumps), it is sufficient for practical purposes to take the temperature of the water at the source of supply, whether the feeding instrument is a pump or an injector.

When there are two independent sources of feed water supply, one the main supply from the hot well or from some other source, and the other as auxiliary supply derived from the water condensed in the jackets of the main engine and in the live steam reheater, if one be used, as often occurs, they are to be treated independently. The remarks already made apply to the first or main supply. The temperature of the auxiliary supply (if carried according to usual practice by an independent pipe either direct to the boiler or to the main feed pipe near the boiler), is to be taken at convenient points in the independent pipe.

When a separator is used in the main steam pipe arranged so as to discharge the entrained water back into the boiler by gravity no account need be made of the water thus returned. Should it discharge either into the atmosphere to waste, or into the hot well, or into the jacket tank, its temperature is to be determined at the point where the water leaves the separator before its pressure is reduced.

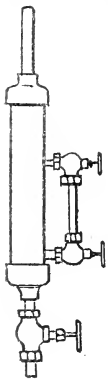
When a separator is used and it drains by gravity into the jacket tank, this tank being subjected to boiler pressure, the temperatures of the separator water and jacket water are each to be taken before their entrance to the tank.

Should there be any other independent supply of water, the temperature of that is also to be taken on this preliminary test.

3. The engine is now stopped for a time in order, first, to connect up the measuring apparatus for determining the weight of the feed water consumed, or of the various supplies of water if there are more than one; and, second, to test the leakage of the plungers.

In order that the main supply of feed water may be measured, it will generally be found desirable to draw it from the cold water service main. When this is done the best form of apparatus for weighing the water consists of two tanks, one of which rests upon a platform scale supported by staging, while the other is placed underneath. The water is drawn from the service main into the upper tank, where it is weighed, and then it is emptied into the lower tank. The lower tank serves as a reservoir, and to this the suction pipe of the feeding apparatus is connected.

The jacket water may be measured by using a pair of small barrels, one being filled while the other is being weighed and emptied. This water, after being measured, may be thrown away, the loss being made up by the main feed pump. To insure no evaporation from the water and consequent loss on account of its highly heated condition, each barrel should be partially filled with cold water previous to using it for collecting the jacket water, and the weight of this water treated as *tare*. Where the jacket water drains back by gravity to the boiler, waste of live steam during the weighing should be prevented by providing a small vertical chamber and causing the water to collect in this receptacle before its escape. A glass water gauge is attached so as to show the height of water inside the chamber, and this serves as a guide in regulating the discharge valve. The chamber may be made of piping in the manner shown in the appended sketch.



A.

When the jacket water is returned to the boiler by means of a pump the discharge valve should be throttled during the test, so that the pump may work against its usual pressure, that is, the boiler pressure, as nearly as may be, a gauge being attached to the discharge pipe for this purpose.

When a separator is used and the entrained water discharges either to waste, or to the hot well, or to the jacket tank, the weight of this water is to be determined, the water being drawn into barrels in the manner pointed out for measuring the jacket water. Except in the case where the separator discharges into the jacket tank, the entrained water thus found is treated, in the calculations, in the same manner as moisture shown by calorimeter test. When it discharges into the jacket tank, its weight is simply subtracted from the total weight of water fed and allowance made for heat of this water lost by radiation between separator and tank.

When the jackets are drained by a trap, and the condensed water goes either to waste or to the hot well, the determination of the quantity used is not necessary to the main object of the duty trial, because the main feed pump in such cases supplies all the feed water. For the reasons which are noted in paragraph 4, however, it is desirable that this water be measured, whatever the use to which it is applied.

Should live steam be used for reheating the steam in the intermediate receiver, it is desirable to separate this from the jacket steam, if it drain into the same tank, and measure it separately. This, likewise, is not essential to the main object of the duty trial, though useful for purposes of information.

The remarks as to the manner of preventing losses of live steam and of

evaporation, in the measurement of jacket water, apply to the measurement of any other hot water under pressure which may be used for feed water.

Should there be any other independent supply of water to the boiler besides those named, its quantity is to be determined independently, apparatus for all these measurements being set up during the interval between the preliminary run and the main trial, when the plant is idle.

The quantity of water which leaks by the plungers is most satisfactorily determined by removing the cylinder heads. A wide board or plank is temporarily bolted to the lower part of the end of the cylinder so as to hold back the water, in the manner of a dam, and an opening is made in the temporary head thus provided for the reception of an overflow pipe. The plunger is blocked at some intermediate point in the stroke (or if this position is not practicable at the end of the stroke) and the water from the force is admitted at full pressure behind it. The leakage escapes through the overflow pipe and it is collected in barrels and measured. The test need not continue over fifteen minutes, or if carefully made, a less time, the desired object being to get a satisfactory determination of simply the rate of leakage. If no means exists for putting the back side of the plunger under water pressure, a suitable pipe can readily be provided for this purpose. Should the escape of the water into the engine room be objectionable, a spout may be constructed to carry it out of the building. Where the leakage is too great to be readily measured in barrels, or where other objections arise, resort may be had to weir or orifice measurement, the weir or orifice taking the place of the overflow pipe in the temporary wooden head. The apparatus may be constructed in a somewhat rude manner and be sufficiently accurate for practical requirements.

In the case of a pump from which it is difficult to remove the cylinder head, it may be desirable to take the leakage from one of the openings which are provided for the inspection of the suction valves, the head being allowed to remain in place. If the test is made without removing the head, leakage of the discharge valves may be confounded with leakage of the plunger. Examination for such leakage should be made first of all, and if it occurs and it is found to be due to disordered valves, it should be remedied before making the plunger test. The discharge valves on the back end of the pump should likewise be examined, as also the suction valves on both ends, and the disordered valves removed. Leakage of the discharge valves will be shown by water passing down into the empty cylinder at either end when they are under pressure. Leakage of the suction valves will be shown by the disappearance of water which covers them.

The leakage test being completed, no change is allowed in the adjustment of the packing of the plunger (supposing this to be of a form capable of adjustment), the head is immediately replaced and preparations made for at once beginning the main duty trial.

4. The duty trial is here assumed to apply to a complete plant, embracing a test of the performance of the boiler as well as that of the engine. The test of the two will go on simultaneously after both are started, although the boiler test will begin a short time previous to the com-

mencement of the engine test and after the engine test is finished. The mode of procedure is as follows:

While the preparations are being made to start the engine, after the completion of the leakage trial, steam is raised in the boiler to the working pressure. The fire is then hauled, the furnace and ash pit cleaned, and the test of the boiler is commenced. This test is made in accordance with the rules for a standard method recommended by the Committee on Boiler Tests of the American Society of Mechanical Engineers. This method, briefly described, consists in starting the test with a new fire lighted with wood, the boiler being previously heated to its normal working degree; operating the boiler in accordance with the conditions determined upon; weighing coal, ashes and feed water; observing the draught, temperatures of feed water and escaping gases, and such other data as may be incidentally desired; determining the quantity of moisture in the coal and in the steam; and at the close of the test hauling the fire and deducting from the weight of coal fired whatever unburned coal is contained in the refuse withdrawn from the furnace, the quantity of water in the boiler and the steam pressure being the same as at the time of lighting the fire at the beginning of the test. Previous to the close of the test the fire is burned down to a low point, so that the unburned coal withdrawn is in nearly a consumed state. The temperature of the feed water is observed at the point where the water leaves the engine heater, if this be used, or at the point where it enters the flue heater, if this apparatus is employed. In either case where an injector is used for supplying the water, a deduction is to be made for the increased temperature of the water due to this method of feeding.

As soon after the beginning of the boiler test as practicable, the engine is started and preparations are made for the beginning of the engine test. The formal commencement of this test is delayed till the plant is in normal working condition, which should be not over one hour after the time of lighting the fire. When the time for commencement arrives, the feed water is momentarily shut off, and the water in the lower tank is brought to a mark. Observations are then made of the number of tanks of water thus far supplied, the height of water in the gauge glass and the indication of the counter on the engine, after which the supply of feed water is started and the regular observations of the test commenced. The test is to continue at least 10 hours. At its expiration the feed pump is again momentarily stopped, care having been taken to have the water slightly higher than at the start, and the water in the lower tank is brought to the mark. When the water in the gauge glass has settled to the point which it occupied at the beginning, the time of day and the indication of the counter observed, together with the number of tanks of water thus far supplied, and the engine test is held to be finished. The engine continues to run after this time till the fire reaches a condition for hauling and completing the boiler test. It is then stopped and the final observations relating to the boiler test are taken.

The observations to be made and data obtained for the purposes of the engine test embrace the weight of feed water supplied by the main feeding apparatus, that of the water drained from the jackets and any other

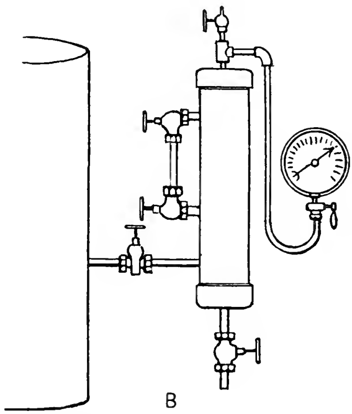
water which is ordinarily supplied to the boiler, determined in the manner already pointed out. They also embrace the number of hours duration and number of strokes of the pump during the test, as noted, together with the length of the stroke (in direct acting engines), the indication of the gauge attached to the force main, and indicator diagrams from the pump. It is desirable that indicator diagrams be obtained also from the steam cylinders.

Observations of the length of stroke should be made every five minutes; observations of the water pressure gauges every fifteen minutes; observations of the remaining instruments, such as steam gauge, vacuum gauge, thermometer in pump well, thermometer in feed pipe, thermometers showing temperature of engine room, boiler room and outside air thermometer in flue, thermometer in steam pipe if the boiler has steam heating surface, barometer and other instruments which may be used, every half hour; indicator diagrams should be taken every half hour, both from the steam and from the water cylinders; should the diagrams from the pump be rectangular, they may be taken, if desired, with less frequency.

When the duty trial embraces simply a test of the engine apart from the boiler, the course of procedure will be the same as that described; excepting that the fires will not be hauled and the special observations relating to the performance of the boiler will not be taken.

5. In making preparation for the test, attention should be given to the following provisions in the arrangement of the apparatus :

The gauge attached to the force main is liable to a considerable amount of fluctuation unless the gauge cock is nearly closed. The practice of choking the cock is objectionable. The difficulty may be satisfactorily overcome and a nearly steady indication secured, with cock wide open, if a small reservoir having an air chamber is interposed between the gauge and the force main in the manner shown in the appended sketch. By means of a gauge glass on the side of the chamber and an air valve, the average water level may be adjusted to the height of the centre of the gauge, and correction for this element of variation avoided.



To determine the length of stroke in the case of direct acting engines, a scale should be securely fastened to the frame which connects the

steam and water cylinders, in a position parallel to the piston rod, and a pointer attached to the rod so as to move back and forth over the graduations on the scale. The marks on the scale, which the pointer reaches at the two ends of the stroke, are thus readily observed and the distance moved over computed. If the length of the stroke can be determined by the use of some form of registering apparatus, this method of measurement is preferred. The personal errors in observing the exact scale marks, which are liable to creep in, may thereby be avoided.

The form of calorimeter to be used for testing the quality of the steam is left to the decision of the person who conducts the trial. It is preferred that some form of continuous calorimeter be used which acts directly on the moisture tested. If either the superheating calorimeter or the wire-drawing instrument be employed, the steam which it discharges is to be measured either by numerous short trials, made by condensing it in a barrel of water previously weighed, thereby obtaining the rate by which it is discharged, or by passing it through a surface condenser of some simple construction and measuring the whole quantity consumed. When neither of these instruments is at hand and dependence must be placed upon the barrel calorimeter, scales should be used which are sensitive to a change in weight of a small fraction of a pound, and thermometers which may be read to tenths of a degree. The pipe which supplies the calorimeter should be thoroughly warmed and drained just previous to each test. In making the calculations, the specific heat of the material of the barrel should be taken into account, whether this be of metal or of wood.

If the steam is superheated or if the boiler is provided with steam heating surface, the temperature of the steam is to be taken by means of a high grade thermometer resting in a cup holding oil or mercury, which is screwed into the steam pipe so as to be surrounded by the current of steam. The temperature of the feed water is preferably taken by means of a cup screwed into the feed pipe in the same manner.

Indicator pipes and connections used for the water cylinders should be of ample size and so far as possible free from bends. Three-quarter inch pipes are preferred, and the indicators should be attached one at each end of the cylinder. It should be remembered that indicator springs which are correct under steam heat are erroneous when used for cold water. When steam springs are used, the amount of error should be determined, if calculations are made of the indicated work done in the water cylinders.

To avoid errors in conducting the test due to leakage of stop valves either on the steam pipes, feed water pipes or blow-off pipes, all these pipes not concerned in the operation of the plant under test should be disconnected.

6. The engine is to be worked on the duty trial, unless otherwise stipulated, at its rated capacity of discharge.

7. In review of the method thus pointed out, the various steps may be summed up briefly as follows:

a. Preliminary run to determine the temperature of the feed water.

b. Erection of weighing apparatus, examination of pump and test of plunger leakage.

c. Commencement of boiler test.

d. Commencement of engine test.

e. Boiler and engine test go on simultaneously.

f. Close of engine test.

g. Close of boiler test.

8. It is desirable that the report of a duty trial should be sufficiently full to show the performance of the engine and its various members in all other respects than the simple expression of the amount of duty performed. For this reason the horse-power developed by the steam cylinders, the feed-water consumption per horse power per hour, the steam accounted for by the indicator and other information relating to the work of the engine in the capacity of a steam engine should be determined and given.

The efficiency of the mechanism of the engine should also be determined and stated; that is, the proportion which the work done upon the water bears to the work done in the steam cylinders. This efficiency may be expressed by the formula,

$$\text{Efficiency} = \frac{(CVwN - L) \times (H \pm s + h)}{W} \text{ in which}$$

the numerator is the expression used in the formula for duty, and the denominator is the number of foot pounds of work done during the trial, measured from the indicator cards taken from the steam cylinders. This last may be determined by multiplying the indicated horse power by 1,980,000 and the product by the number of hours' duration of the trial.

DISCUSSION.

By James A. Tilden.

Mr. Barrus has certainly presented a scientific and thoroughly accurate method of conducting duty trials of pumping engines. That the necessity for such a method is very great is unquestioned. There are about as many different methods of conducting duty trials or estimating the duty as there are pumping plants, and there is no standard or uniform method whereby any adequate comparison can be made between engines of the same or different manufacture. In a general way the work is referred to the number of pounds of water elevated one foot by a hundred pounds of coal. Mr. Barrus has explained in how many ways this may be interpreted, but the permutations and combinations of the different *allowances* which are made by different engineers produce a variety of results which is something astonishing.

There are, however, certain practical difficulties in the way of introducing a standard method which will more or less affect its adoption. These difficulties will arise from the objections of the manufacturers of pumping engines, from those who use them, and from expert engineers. The present methods of conducting duty trials are satisfactory enough to engine builders on account of the reasons given by Mr. Barrus. It is a very easy matter to represent to a water board when it is desired to make a sale, that the engine will perform a very acceptable high duty, and then when it comes to the trial, make a certain combination of "allowances" which will bring the duty equal to, or in excess of, the

figure named. As stated in the paper in discussion, the contract is generally sufficiently ambiguous to allow the manufacturer to obtain the duty guaranteed.

This is no argument against the equity of a standard method, but simply represents the probable disfavor from this source.

Since the reading of the paper in January, I have made personal inquiry of a number of eminent waterworks engineers in charge of extensive water-works in different parts of the country, as to the favor with which a standard method of conducting a duty trial would be received by them, and I find that each has his pet method, and in case of purchase of a new pumping engine, he would conduct his duty trial in the same manner as he had been in the habit of doing, so as to make a comparison between the new engine and the old on the same basis.

From a very well known water works engineer I obtained expressions of very marked indifference. He said all he cared to know was how many foot pounds of work he obtained for a hundred pounds of such coal as he commonly used, the engine builders taking the boilers and apparatus just as they found them. This sentiment he had fully carried out in practice, having just put in two twenty-million engines. He said, further, that that represented in a perfectly simple way the actual work done by a hundred pounds of coal under the special conditions at their pumping station, and gave a comparison easily understood of the work done by the new engines and the old. In this case absolutely no "allowances" were made. This single instance illustrates that peculiar ideas are entertained by reputable engineers in charge of water works which would be more or less difficult to overcome. The unscientific citizen, moreover, is more or less suspicious of what he terms "fancy scientific tests." By unscientific citizens I mean the average member of a water board. He can, without difficulty or special education, count the number of wheel-barrow loads of coal, and note the weight of each, which go to the boiler, and, obtaining from the counter of the engine the number of strokes of the pump, he can make a simple calculation, and satisfy his own mind that the new pumps are pumping more water for a given amount of coal than the old ones, or *vice versa*. This represents, I think, an actual condition of affairs which will have to be met.

Objections to a standard method by expert engineers will arise from the variety of conditions under which tests are to be made. For instance, if a feed-water heater is in use, which is imperfect in operation, or overcrowded, will the expert discriminate against the engine builder because of such imperfect conditions? Or if the donkey pump already in use in the plant uses five per cent. of the steam instead of three, is that difference of two per cent. to be reckoned against the duty of the new engines? The same question applies to the use of an independent air-pump, where the entire plant, engines, boilers, and all the accessories, are furnished by the same party. A general objection appears that certain "allowances" under certain conditions are and will have to be made under any standard however complete.

The method, from a scientific point of view, proposed by Mr. Barrus appears to be entirely without exception. A pumping engine should

undoubtedly be treated as a heat engine, and the adoption of 1,000,000 B. T. U. is a convenient standard to which to refer the duty of an engine.

Where all prejudice, such as above discussed, can be overcome, the method proposed by Mr. Barrus will undoubtedly prove very acceptable and will come into general popular favor.

In an oral discussion at the January meeting, I made a few remarks relative to the use of the water end of the pumping engine as a water meter, that is, calculating by the number of strokes and the diameter and travel of the water plungers the amount of water pumped, and made some criticisms as to the degree of accuracy obtained thereby. There are two parts to a pumping engine which are separate and distinct, the steam end and the water end. The steam end can be treated in precisely the same manner as a steam engine, and its efficiency ascertained minutely. But there has been a tendency to slight the water end and take certain things for granted. Every other portion of the test is conducted with a view to obtaining the efficiency of the several parts of the apparatus to a fraction of one per cent., and in point of time, is continued throughout the entire test.

There is, unfortunately, very little data as to the slip or loss of action under varying conditions. Difference of pressure may make a variation of one per cent., or perhaps two per cent. under extreme limits. The rate at which the plungers move affects the slip to a great extent. There is a rate at which a pump could run which would be so slow as to just equal the slip, in which case the slip would be the entire amount or one hundred per cent.

On the other hand, there is a rate at which the loss would be the minimum quantity, which may be as low as one per cent. A variation from this rate either faster or slower will result in a greater slip. It is on this account that engines on a direct pumping system have a greater loss of action than on a reservoir or stand-pipe system. The continual change in the rate must necessarily produce a greater slip. The writer has an instance of this kind in mind, where in first class pumps on a direct pumping system under the direction of a well known engineer, an allowance of seven per cent. between the actual plunger displacement and the amount pumped is made. This was the engineer's estimate based upon long experience.

The best results obtained have been on a reservoir system under constant head and rate. Here a loss of as little as one per cent. has been obtained between plunger displacement and weir measurement. This presumes on its face that weir measurement is accurate, but considerable question is raised as to whether it approximates accuracy within even one or two per cent.

There is a difference between the loss in clear water and dirty water, especially in water containing substances of a stringy or fibrous nature. These substances prevent the full closing of the valves and is sufficient to account for a very considerable loss. Muddy or sandy water is not so bad, as any particles of this kind would be either washed off the seat or imbedded in the rubber of the valve in closing. Cards from the water end may be relied upon to indicate any great loss from this cause or from the presence of air.

These remarks are offered for the purpose of prompting further discussion, and to advance the opinion that under any uniform method certain "allowances" would have to be made in many cases, depending upon the conditions, and these "allowances" would still furnish a field for difference of opinion, and impair the value of the tests for the purpose of comparison. The opinion is further advanced that it is in the water end of the pump that the only uncertain factor is found in obtaining perfect accuracy of test. No better plan or remedy for this uncertainty is entertained, but with attention called to the various points some plan may be suggested which may be of value.

By John E. Cheney.

The subject treated by Mr. Barrus in his very interesting and able paper is one of importance to all purchasers and users of pumping machinery.

The writer has for a long time believed that in purchasing pumping plant, the efficiency of a pumping engine should be considered independently of that of the boiler, especially when new engines are to be used in connection with old boilers, or when the engine and boiler are to be furnished by different parties.

It will, probably, be somewhat difficult to prescribe a standard method for conducting duty trials that will be satisfactory to all engineers, and the selection of a common unit or measure for computing the duty may be equally difficult.

Mr. Barrus' paper is a strong plea for a standard method, and it is to be hoped that it will be the means of exciting sufficient interest in the matter to bring about the desired end.

The formula recommended in the paper is intended to be general, and applicable to all cases and conditions under which duty trials are desired, but it would appear that provision has not been made for the following described case :

If the main feed-water is taken from the force main, city pipes, or a natural supply, the temperature of the water will vary in accordance with the season of the year in which the trial is made, or from other circumstances, and in case jacket-water is combined with it, the resultant temperature of the feed-water will vary in the same amount as the initial temperature. Therefore the item of heat consumed by the engine, embraced in "weight of water supplied by main feed-pump, multiplied by total heat of steam of boiler pressure above temperature of main feed water," will vary in accordance with the initial temperature of the feed-water.

The high duty pumping engines of the Boston Main Drainage Works have jet condensers, using salt-water injection, and present an example where the varying initial temperature of the feed-water, due to the season of the year, would affect their duty as computed by Mr. Barrus' formula.

On August 9, 10, August 22, 23, and September 26, 27, tests were made to ascertain the duty of the new high-service pumping-engines at Chestnut Hill, and also to determine the efficiency of the boilers connected with them.

The general specifications under which bids were received were prepared by the City Engineer, in June, 1886, and the following extracts from them will show the capacity and duty required of the engines, and the methods prescribed for ascertaining the same.

The engines are each to have sufficient capacity to easily deliver into the Fisher-Hill reservoir, so called, 8,000,000 United States gallons of water per twenty-four hours, the total lift being from 116 to 128 feet.

The loss of action in the pumps must not exceed 4 per cent.

The piston speeds per minute, for the above-named capacities, are not to exceed, for direct-acting engines 110 feet, and for beam and fly wheel engines (vertical), 200 feet.

As the efficiency of the engines is required to be shown independently of that of the boilers, the calculation of the required duties of the engines will be based upon a unit of water evaporated into dry steam in the boilers, the equivalent of which shall be 1,100 pounds of water evaporated from and at 212 degrees Fahrenheit.

Each engine will be required to exhibit a duty of 100,000,000 foot-pounds per before specified unit of water evaporated into dry steam in the boilers.

The duty trials, one for each engine, will be conducted in the following manner: Steam will be raised in the boilers to the lowest pressure at which the engines will run at full speed for capacity, when the fires will be hauled, the furnaces and ash-pits cleaned, and fresh fires started with as little delay as possible. As soon as the fires are well ignited the engine will be started and run at full speed for capacity, with the working pressure of steam for twenty-four hours. At the latter part of the trial the fires will be burned down until the steam-pressure in the boilers is the same as at the beginning of the trial, when the engine will be stopped. The amount of water in the boilers is to be the same at the end as at the commencement of the trial. During the trial the pressure and temperature of the steam and the temperature and weight of water supplied to the boilers will be carefully noted. Calorimeter tests will be made to determine the quality of the steam supplied to the engines, and steam containing not more than 3 per cent. of entrained water will be considered dry steam.

The duty of the engine will be computed as follows: The area of the plunger in feet will be multiplied by the pressure in pounds, due to the total left in feet, which will be obtained from the average reading of a correct pressure-gauge, attached to the force-main, near its connection to the pump, to which will be added the pressure due to the difference of level between the zero of the gauge and the water in the pump-well; the product thus obtained will be further multiplied by the total number of feet traveled by the plungers on their discharging strokes. This product equals the total work in foot-pounds. The amount of water evaporated by the boilers during the trial will be reduced to an equivalent number of pounds of water evaporated from and at 212 degrees Fahrenheit. The total work in foot-pounds divided by this equivalent evaporation, and the quotient multiplied by 1,100, will be the duty of the engine in foot-pounds, per specified unit of water evaporated into steam. All steam used for feed-pumps, condensers, and other appliances, will be taken from the boiler furnishing steam to the engine, and no allowances will be made for steam so used.

The efficiency of the boilers will be tested at the duty trials.

Capacity tests of the engines will be made either in conjunction with the duty trials or separately; the amount of water pumped to be determined by weir-measurement at the Fisher-Hill reservoir.

The duty trials will be conducted by the City Engineer, and the expense of them will be borne by the City.

The contractor, or his representatives, may be present at the duty and capacity trials of the engines, and may have access to all instruments used and notes taken.

It will be noted that, in accordance with the specifications, the duty of the engines was to be computed upon a unit of steam used by them, instead of upon the usual unit of coal burnt under the boilers. The duty of the engines was, therefore, to be shown in terms of heat furnished to, and consumed by them. The unit of steam used was made large, and consequently no allowances were made for any steam not used by the engine proper, and for any heat returned from the engine to the boiler.

The duty required by the specifications can be expressed in general terms as,—

$$\text{Duty per 1,100 pounds water evaporated from and at 212} = \frac{\text{Work done in ft.-lbs.} \times 1{,}100.}{\text{Equivalent lbs. of water evaporated from and at 212}}$$

At the trial of Engine No. 2, made on September 26, 27, the work done was 8,754,116,000 foot-pounds, and the weight of water fed to the boiler

and evaporated into steam at 79.9 pounds pressure, was 88,453 pounds. The equivalent evaporation from

$$212 \text{ was } 88,453 \times \frac{1,000}{966} = 91,566.25 \text{ lbs.}$$

Then,—

Duty per 1,100 lbs. water evaporated from and at 212°

$$= \frac{8,754,116,000 \times 1,100}{91,566.25} = 105,164,600 \text{ ft.-lbs.}$$

The specified unit of water evaporated into steam equals 1,100 pounds of steam made from and at 212°, and this can be expressed by the 1,062,-600 heat units contained therein. By adapting the formula to this expression of the specified unit, it becomes general in character and application, and appears in the following form:

Duty per 1,100 pounds steam made from and at 212°

$$= \frac{W \times 1,062,600}{U - u} \text{ in which}$$

W = Work done by engine in ft.-lbs.

U = Heat units in total steam used, in excess of heat units in equal weight of water at 212°.

u = (1st) Heat units returned from engine to boiler, plus (2d) heat units in steam used for any purpose other than running the engine, in excess of heat units in equal weight of water at 212°.

The duty of engine No. 2, as per trial of September 26, 27, is shown by the formula, as follows:

Duty per 1,100 pounds steam made from and at 212 degress = $\frac{8,754,116,000 \times 1,062,600}{88,453 \times 1.000} = 105.164,600$ feet-pounds, the same result as obtained by the specified formula.

In the above mentioned trial the heat of the feed-water was increased 38.9 by the addition of the jacket-water, and the amount of heat returned to boiler from engine therefore equals 88,453 × 38 9 = 3,440.821.7 heat units. The net duty of engine per 1,100 pounds steam made from and at 212° then equals $\frac{8,754,116,000 \times 1,062,600}{88,453,000 - 3,440,821.7} = 109,421,100$ feet-pounds.

In case calorimeter tests of the steam had been made, u would have been increased by the addition of the heat units contained in steam used for the tests, in excess of heat units in equal weight of water at 212°.

By E. D. Leavitt.

The late Henry R. Worthington was once engaged in negotiating a sale of a pumping engine to the president of a prominent water commission who was by occupation a printer. After considerable talk about duty, during which very little progress was made towards an understanding, Mr. Worthington exclaimed: "I don't know much about duty, but I will agree to put so many gallons of water into your reservoir with so many pounds of coal." "Now I understand you," said the president, and the trade was consummated without further delay.

As a preliminary to the adoption of Mr. Barrus' methods, the American Water Works Association, or some kindred organization, should establish a great technical institute for the education of water com-

missioners, water works superintendents and employés in the principles of thermodynamics—an undertaking the magnitude of which is comparable only with the preposterous claims of the average pumping engine builder for high duty.

The method of test proposed by the author, viz., the accurate determination of the amount of heat expended to produce a given amount of work, is one which, if carried out in practice, would add greatly to our stock of engineering data. On this ground I would, for the greater part, indorse it; but I cannot agree with the author as to the desirability of making such a test a part of the contract requirements. It is a fact, as the author remarks, that in the majority of cases the purchaser knows very little about the subject of duty tests, but for this very reason I would make the contract requirements as simple as possible, so that the purchaser could understand them, instead of complicating them so that he must be entirely dependent upon his experts. A purchaser is often suspicious of the contractor, and sometimes, with or without reason, has not the fullest confidence in the expert. It is, then, a matter of great satisfaction to all three parties if all the questions at stake are so stated as to be fully understood by all parties concerned.

I do not wish to be understood as deprecating the making of accurate scientific tests. On the contrary, I would in all cases make as complete a test as possible, for several reasons. In the first place, such a test shows to the purchaser's expert where, if at all, the plant can be improved, outside of the contract, so as to give a greater return for money expended; it gives a datum line with which future performances of the same plant can be compared, and any falling off in economy detected and remedied; it shows the builder where to make changes to improve his next design, and it adds to our general fund of information.

From the stand-point of the purchaser the problem appears as follows: Money is to be put out in the purchase of a pumping plant, and afterwards in coal, oil, labor and repairs, and the more water that can be pumped for a given outlay for running expenses and for interest on first cost the better. If he can get a guarantee of a certain quantity of water delivered where he wants it by the expenditure of a given quantity of coal the affair is much simplified. Having such a guarantee, an estimate for furnishing the plant, and the opinion of an expert as to the durability of the proposed machinery, any good business man will soon come to a conclusion as to which of several offers will be the better paying investment. The purchaser and the expert can thoroughly understand each other, and can work in harmony. Suppose, however, that it is proposed to guarantee a certain number of foot-pounds of work for the expenditure of a certain number of thermal units. It is true that the plant that will do the most useful work for the least heat will pump the greatest amount of water to the greatest height for the least coal. This the purchaser can understand, and, as far as a decision as to which plant to select is concerned, it would be all sufficient if the question were to be limited only by the running expenses. But the purchaser wants to know the cost in money for water delivered, so as to compare it with the cost of plant. In the supposed case he must rely entirely upon the figures of the expert. The latter must calculate back from thermal

units to coal, and forward from foot-pounds to gallons of water delivered where wanted. The nearer the guarantee figures can approach the coal pile at one end and the service main at the other, the more fully will all parties understand each other.

The engineer naturally looks at the question from another stand-point. He divides the process into numerous steps, studying the economy of the various stages. Beginning at the furnace, he wants to know how much of the available heat of the coal is brought out by the combustion; how much of this is transferred to the water in the boiler; and how much is lost by going out with the steam in the form of water. He studies the heat converted into work in the cylinder, the heat returned to the boiler from the jackets, separators and re heaters, the heat returned in the feed and lost in the condenser, the water handled by the pump and that actually delivered; the fluid friction below, at, and above the pump, and the many other details upon which the mechanical and commercial success of the plant depends. To him a pound of coal is a very uncertain quantity, and a gallon of water removed from one place and put into another is not an invariable unit of work. He prefers to begin with such a tangible unit as a known quantity of heat, and to end with the well established foot-pound. He could not well do otherwise in his own calculations, for unless he uses established and invariable units he cannot make determinate comparisons of performance, or properly calculate the necessary proportions for his designs. But the purchaser often knows little or nothing of these intermediate steps, and consequently the engineer, when he comes into contact with him, should talk in a language where they stand on common ground.

The simplest case would be where the contractor furnishes the plant complete from suction pipe to service main, including boilers and auxiliary machinery. Here the contract can be made to guarantee a certain amount of water delivered into the reservoir between certain limits of level, or, in the case of direct supply, a certain quantity delivered at a certain point in the service main at a certain pressure, the cost to be expressed in coal of a certain quality. The coal might be specified as to come from a certain mine, to be of a certain size, to be fresh mined or not over a certain age, and to contain not over a certain percentage of moisture. It should be specified, unless utterly impossible, that the test of duty should be made by weir measurement, and a short description of how and where the weir should be fitted might be appended to the contract. Also, perhaps, a description of the method of measuring the fuel used, hauling fires, and starting fresh ones at the beginning of the test, etc. Here there is no break between the two ends of the problem; coal at one end and water at the other; and no intermediate measurements need be made, except for purposes outside the contract. What benefit could possibly accrue to either the purchaser or the contractor by changing from the coal-burned-and-water-delivered basis to the thermal-unit and foot-pound system of measurement? The builders could base their estimates equally on either system, but the purchaser would feel more at home in dealing with the former.

But suppose that the contractor only puts in the pumping plant and auxiliary machinery, taking steam from boilers already in use, or put in

by other parties. In this case two courses are open. If the boilers are of a well-known type the contractor should be able, after an examination of them, or of the drawings of the proposed boilers, to make a close estimate of their evaporative ability, and could offer to pump so much water per unit of coal as in the first case. The rate of combustion should be specified in the contract, and a drawing of the proposed boilers might be appended. If, however, as sometimes happens, the boilers are of some abnormal design, or if for any other reason the contractor declines to guarantee the coal consumption, the problem will be less complicated by guaranteeing the weight of feed water than by making a more scientific basis of calculation. If the contractor doubts the ability of the boilers to furnish dry steam, the contract could specify the limit of allowable moisture and the method of test of the same and of allowance for excess. It should be specified in the contract that in regular service the water drained from jackets, separators, re-heaters and other parts under boiler pressure; should be returned to the boilers without loss of pressure; that water drained from parts under less than the boiler pressure should be drained into a tank, where it would all be taken by the feed pump, and that all other feed should be taken from the hot well, whose temperature should not be less than a given limit. In the case of auxiliary air pumps it might be specified that all feed water pumped to boilers should have a temperature not less than 200 degrees F., being heated by the exhaust steam of the pump. In this way waste of heat in various ways, which might result if only the weight of feed water were specified, would be prevented. The weight of feed water, less that of water trapped out of the steam-pipes, would then be a fair measure of the economy of the plant. To be sure, each pound of steam taken through the jackets and reheaters will require less heat than each pound used in the cylinders, but the difference will be but a small percentage of the total heat used. I notice, by-the-way, that in Mr. Barrus' illustrations he, by an oversight, gives the heat used by each pound of jacket and reheater steam as the total heat due to the pressure, minus the heat returned to the boiler. Now as this steam was kept in the system under boiler pressure, and did no external work, the "external resistance" heat should not have been charged to it. In the third illustration given, for instance, one pound of jacket steam (at 120 pounds gauge pressure) would use $1132.8 - 292 = 840.8$, instead of $1215.9 - 292 = 923.9$ thermal units. In the same way the reheater steam would use only 830.7 thermal units per pound, instead of 913.8. Making these corrections, the heat consumed by the engine would be $(188,000 \times 1,070.6) + (7,000 \times 840.8) + (2,000 \times 830.7) + (3,000 \times 9.9) = 208,849,500$ thermal units. Now if, neglecting the saving of heat by the jacket and reheater, we had roughly assumed the heat used to be equal to the total weight of water fed to the boiler, multiplied by the heat expended per pound of the main feed, or $(188,000 + 7,000 + 2,000) \times 1,070.6 = 210,908,200$ thermal units, we would have been less than 1 per cent. out of the way. But in a comparison of any two engines which would come sufficiently near to each other in heat economy to enter into serious competition, the comparative effect of the error would be much smaller and the weight of feed water

of two engines using practically the same steam pressure and feed temperature could be safely assumed as being proportional to the heat expended within one-half of one per cent. Again, the steam pressure, in a case where a pumping plant is to be connected with existing boilers, would be fixed, but even supposing a latitude of 50 pounds in pressure to be admissible, two competing engines could not differ in the total heat per pound of steam used by more than 10 thermal units, or about one per cent.

It will be seen, then, that if we exact a sufficiently high feed temperature, and specify how all trapped water shall be disposed of, we can, without making any corrections whatever, safely assume the heat value of the steam used to be proportional to the weight of feed water within $1\frac{1}{2}$ per cent., which is certainly sufficiently accurate for commercial purposes. The engineer would, of course, by analysis, arrive at a closer result, but the purchaser, knowing the economic evaporation of his existing boilers, or having a guarantee from the builders of the new ones, could calculate very closely from the guaranteed steam consumption what the cost of coal for pumping a given quantity of water would be. And if the weight of feed water is a sufficiently close measure of cost in selecting an engine, it should certainly be accurate enough for a test requirement. This is not a scientific way of testing an engine, but it is a practical way which any business man can understand.

Turning now to the water end of the pump, I cannot agree with the author that the method of approximating to the water delivery by means of the plunger displacement, is a satisfactory one. With a first-class pump, known to have an insignificant "loss of action," this method would give a sufficiently accurate result, but if it is stipulated in the contract, or is mutually understood, that this will be the sort of test made, too great a temptation is offered to the builders to make an inefficient machine. The difference between the cost of construction of a pump having an insignificant "loss of action" and one in which this loss is a considerable amount, is sufficient to make it an object to build the latter pump instead of the former, unless the test requirement would call for the better machine. The cost of weir measurement is not so great but that it is preferable to go to the expense of making it, rather than run the risk of a large loss of action. It is seldom that the connection of a new pumping plant with the service mains cannot be delayed long enough to make the duty test. The force main can easily be choked down by valve, or by a blank flange with proper sized aperture, to give the necessary head; while the construction of a weir need cost but a nominal sum. It is only when a long conduit for the waste water has to be constructed that the cost of weir measurement becomes excessive.

When, however, the plant is so urgently needed for regular service that a weir measurement cannot be made, recourse must necessarily be had to the plunger displacement method. I would, however, determine the piston leakage at several points in the stroke, and also in both directions instead of at one point and in one direction, as recommended by the author, as inaccurate boring may give varying results in the first case, while piston packings do not always prevent leakage equally in both directions. If a stand pipe is used, several fillings of it might be made

to give an approximation to the loss of action, to be applied as a correction in the duty test.

When the contractor does not furnish the force main, there is no reason why he should not make his calculations of friction from the design of the main, the same as if he were to furnish it himself, so that he need not, on this score, be prevented from guaranteeing a certain delivery into the service main. In such a case it might be advisable to append to the contract a drawing of the force main to be used.

When the contractor furnishes the bare pumping engine, without any auxiliary steam machinery, it is very easy to state in the contract whether or not the steam for these auxiliaries is to be counted in the duty test. It is in the drawing up of the contract and specifications that it is necessary to exercise the greatest care. "An ounce of prevention" at this point "is worth a pound of cure" in settling disputes as to the proper method of test.

A standard such as the author proposes, with slight modifications, would be of great value for purposes of scientific comparison; but I do not consider it practicable, for the reasons given, for commercial purposes.

By George H. Barrus.

Replying to the gentlemen who have taken part in the discussion of this paper, it may be well to first refer to the causes which lead the writer to prepare it:

Mr. J. S. Coon, of Burdette, N. Y., read a paper on the subject of "Duty Trials" before the Nashville meeting of the American Society of Mechanical Engineers, which took place in May, 1888. The discussion of this paper resulted in the appointment of a committee composed of members of the American Society of Mechanical Engineers, to determine upon a standard method of conducting duty trials. This committee consisted of Messrs. Coon, de Kinder, Nagle, Reynolds and the writer. It was partly in view of the work of this committee and partly for the purpose of complying with the invitation of the Boston Society of Civil Engineers, which had been received by the author some time before, that the paper was prepared. It is the desire of the committee to obtain the views of experts and others interested in the subject, on the best method of determining upon the proposed standard, and the opportunity of obtaining the ideas of the members of the Boston Society, which is thus presented, is gladly embraced.

In looking over Mr. Leavitt's remarks, which, on the surface, strike one as being an elaborate review of the paper, no statement appears, that, in his opinion, any standard method of conducting duty trials would be of value for commercial purposes, though he admits that it would be quite desirable for scientific comparisons.

The paper, at the outset, lays down the premise that a standard is desirable, not only for the purpose of scientific comparisons, but for commercial uses as well, and the commercial object is quite as important as the other. If Mr. Leavitt does not believe that this is true, and he evidently does not, there seems to be little need of answering the objections,

which, with these views, he finds it easy to raise. It may be well, however, to briefly notice the points which he brings out; for Mr. Leavitt is a hydraulic engineer of large experience in the design and construction of pumping machinery; he is consulting engineer for one of the leading pump manufacturers of the country, and he is presumably associated more or less intimately with the purchasers of pumping engines; all of which places him in a position to express an opinion upon the subject.

Mr. Leavitt's principal objection to the paper is that the proposed standard is not one which should be made a part of contract requirements. The reason given is that the purchaser knows little about thermal units and foot-pounds of work, the two units which are proposed for the standard method. The purchaser, he says, is familiar with the common terms by which coal measurements are expressed, also those of water measurements and of distance; but he will be confused if thermal units are substituted for coal, and foot-pounds for gallons of water raised to a given elevation. Instead of the method proposed in the paper, Mr. Leavitt suggests the following named plans:

First.—Have the duty expressed as the number of gallons of water delivered into the reservoir, between certain limits of level, or delivered at a certain point in the service main at a certain pressure, by 100 pounds of coal. This he would have done in all cases where the contractor furnishes a complete plant, the water being measured, if possible, by a weir. He would have the contractor specify the kind, character, and other properties of the coal used, as also the method of procedure to be followed in conducting the test, not only that part of the test relating to the measurement of the coal, but that part relating to the construction of the weir.

Second.—If weir measurement cannot be resorted to, plunger displacement should be used, allowance being made for the leakage of the plunger.

Third.—If the contractor supplies the engine, and does not supply the boilers, he would have the contractor estimate the evaporative efficiency of the boilers, and base his guarantee on coal consumption in accordance with this estimate. Either this, or he would base the duty on the weight of feed water consumed. In the latter case, he would have the contract specify how the quality of steam is to be determined and allowed for. He would have certain requirements in regard to the disposition of the water drawn from the jackets, separators and re-heaters and such other condensed water as the plant may produce. Also certain stipulations as to the heating of the feed water to a temperature of 200 degrees, by means of the exhaust steam of auxiliary pumps, if any are used.

Mr. Leavitt thus proposes three or four different methods of duty trials for as many different cases, and none of them bear the mark of simplicity which he advocates for contract use.

It may be asked, where is the purchaser of a pumping engine who would sign a contract having these stipulations, and do it with an intelligent idea of its bearing on the question with which he is at home—that is, the number of gallons of water raised to a certain elevation with 100 pounds of coal? And again, wherein does Mr. Leavitt simplify the matter of duty guarantees, which he maintains should be expressed in lan-

guage which an unscientific purchaser can grasp, by overloading the contract with detailed stipulations as to the manner of conducting the test, which only an expert can understand?

Mr. Leavitt leaves the subject just where he found it, and he leaves it in the very same chaotic state which lead the American Society of Mechanical Engineers to determine upon a standard method of performing these operations. The proposed standard, instead of being impracticable for commercial purposes, as Mr. Leavitt affirms, is quite the reverse. The simple stipulation as to the duty test, which is required for a contract, is that the "test shall be conducted in accordance with the standard method determined upon by the authority named." As to the basis of 1,000,000 thermal units, the unscientific purchaser is a very poor business man if he cannot understand that this is nothing more than a precise method of indicating the equivalent of 100 pounds of good coal.

Mr. Leavitt criticises some of the computations given in the paper. He says, in substance, that the heat required to produce a pound of steam at 120 pounds pressure, if used in the jacket, is 1132.8 thermal units, while if used in the engine it is a greater quantity, being 1215.9 thermal units. In other words, the heat required to generate a pound of steam varies according to the uses to which the steam is to be applied. This is a most unwarrantable mistake. Jacket steam, it is true, operates in a closed circuit, and in a commercial sense does no external work of the kind imparted by the cylinder steam. Jacket steam in the process of generation, however, absorbs heat equivalent to the "external work" required to generate it, and its properties in this respect are exactly the same as those of steam used in the cylinder.

Mr. Tilden's remarks bring out many points for thoughtful consideration. In answer to the objection which he raises, that the proposed standard will meet with difficulties in the way of its adoption among water-works engineers, it may be said that the standard does not interfere with the practices which water-works engineers have, in the past, employed. They may continue to use the method of conducting tests to which they have been accustomed. The adoption of a standard will, however, enable them to bring the results which they have already obtained, and which they may obtain in the future, to some common unit of reference, if they, or others, should, for any reason, desire to make comparisons with other engines than those over which they have charge.

As to the variety of conditions under which engines are liable to be used and the objection that certain allowance would need to be made for certain conditions, it appears that no difficulty need arise in treating of this matter. If the engine builder introduced one of his machines in a place where the conditions were not favorable for gettlng the best results, as in the case, for example, which Mr. Tilden mentions, where the donkey pump may use 5 per cent. of steam, instead of a more economical 3 per cent., the builder, in making up his guarantee, must take into account that the engine will work under these unfavorable conditions. He would then simply make the guarantee figure somewhat less than he would otherwise make it.

There is no doubt of the varying quantities of slip in different engines,

produced either by imperfect valves, leaking plungers, or impure water. The question of the leakage of the plungers has been treated in the paper, and the proposed standard allows for it. The question of imperfect valves is also dealt with, but nothing is mentioned in regard to water which contains foreign substances, which would clog the valves. There are few cases, it would appear, where foreign substances contained in the water, which would produce disorder, cannot be removed before they become lodged in the pump, and at all events, this could be attended to during the comparatively short time when the tests are going on. It is true that the proposed method makes no allowance for differences in the quantity of water discharged, due to variations in the loss of action produced by different types of valves, and herein is an element of uncertainty, which there appears to be no means of overcoming. As stated in the paper, it is believed by the writer that in the case of modern pumping engines, the loss of action in the valves is small at best, and, therefore, variations in this loss in pumps of different make would have an almost imperceptible effect upon the duty.

Mr. Cheney's objection, that the proposed standard makes no allowance for a case where the feed water is obliged to be taken from a cold reservoir supply, can easily be met. In a case of this kind, where it was necessary to use the water from some other source than the hot well, as, for example, an engine which was supplied with a jet condenser, using salt water for injection, it would seem that the builder should provide the engine with an exhaust steam heater, whereby some of the heat of the exhaust steam could be returned to the feed water. A temperature of 120 degrees can readily be obtained by the use of a heater of this kind, and this temperature is somewhat above the ordinary temperature of hot wells. If the contractor does not supply such a device, he ought to suffer the consequences, that is, his engine should not get the credit of any allowance for the low temperature of the feed water, or for variations in that temperature due to the season of the year.

THE SANITARY CONDITION OF THE WATER SUPPLY OF NEW YORK CITY.

By Charles C. Brown, Member Engineers' Club of St. Louis.

[Read April 17, 1889.]

Almost ever since the Croton River has been in use as a supply of water for the city of New York, there have been periodical attacks made upon the purity of the water, and much discussion of the subject in the newspapers. A great deal of the matter thus published can be classed as sensational news, but there has been a basis of fact to the exaggerated accounts.

It is quite evident that a territory whose drainage is in large part used for a public water supply, must be kept comparatively clear of population and manufacturing operations or a progressive deterioration of the quality of the water must result. No attempt at such regulation of the water-shed of the Croton has heretofore been made. The region is quite close to the city, its nearest point being about 35 miles distant. The

census reports show a slow increase in population up to 1880. It is probable that the increase since that time has been somewhat more rapid. The population on the water-shed is now estimated at nearly 25,000. No pains have been taken to keep the drainage from the habitations of these people out of the streams, except in a few flagrant cases to which special attention has been called by some interested party. In fact, it has been found that the tendency is to expedite the transmission of such drainage to the streams, and some of the most flagrant cases are still to be found, as they are partially concealed from view and have escaped the notice of self-appointed inspectors. There can be no doubt that years of this sort of work will result in a condition of the water such that it cannot be used for domestic purposes. Chemical analyses of the water, if sufficient in number and reasonably near being consecutive in point of time, should show the results of this neglect of the water. Actual inspection of the water-shed would show the extent of the polluting processes to which the water is subject.

I. The case from the standpoint of chemical analysis is as follows. I am indebted to Professor Elwyn Waller, Ph. D., of Columbia College, New York City, for the most complete set of tables of results of such analyses which has yet been published. He was for a number of years chemist to the city Health Department, and has made a large part of the analyses himself. The tables are printed in full in my Report to the State Board of Health of New York on this subject. In that report, Plate LXX gives a plot of the results for the years for which the most complete series of results were obtained, 1876, 1885–6, and 1888. The principal constituents of the water on which an estimate of its purity is based are *total solids*, the total amount of solid matter obtained by evaporating 100,000 parts by weight to dryness ; *hardness*, the soap-destroying power of the alkaline constituents, in their equivalent of parts of carbonate of lime per 100,000 ; *albuminoid ammonia*, obtained by distillation with potassium permanganate and potash, and deducting from the total ammonia thus obtained the amount of *free ammonia* obtained from a like amount of water distilled with a solution of sodium carbonate (supposed to give an indication of the nitrogenous organic matter present, which has not yet been decomposed sufficiently to furnish free ammonia); *chlorine*, usually in the form of sodium chloride ; *nitrogen*, the total amount of combined nitrogen contained in the water being that contained in the ammonia added to that found in nitrates and nitrites. Chlorine usually indicates contamination by sewage, when proper allowance is made for proximity to the sea, for salt springs, salt in strata, etc. Albuminoid ammonia is taken to indicate pollution from vegetable sources when the amount of chlorine is small. Free ammonia usually indicates fully decomposed polluting matter, and is not of much importance as regards the present purity of the water, unless the amount of albuminoid ammonia is large. The amount of free ammonia in the Croton water is very small when there is any. Tests have been made at intervals for phosphates and nitrites, but without result. Tolerably complete series of determinations of total solids and hardness have been made since 1872. The series of determinations of the other impurities mentioned are very much broken, and in but one case extend back of 1876. The results

of all determinations are given in Professor Waller's tables, above mentioned. I have made averages of the results obtained in each month, which averages are given in the following table. The first column gives the number of results obtained during the month named on the same line in the second column. The third, fourth, fifth and sixth columns give the averages of these results in each month for the various matters above enumerated. All results are given in parts per 100,000.

MONTHLY AVERAGES OF RESULTS OF CHEMICAL EXAMINATIONS OF CROTON WATER.

Parts per 100,000.

No. of Results.	Month.	Total solids.	Hardness.	Albuminoid ammonia.	Chlorine.	Combined nitrogen.
			1872.			
1	May	6.60	....	......	......	......
4	November	8.24	3.36	......	......	......
4	December	7.60	4.10	......	......	......
			1873.			
4	January	7.25	3.05	......	......	......
4	February	7.07	2.95	......	......	......
5	March	7.84	3.17	......	......	......
4	April	6.20	2.85	......	......	......
5	May	6.80	4.00	......	......	....
4	June	8.30	3.68	......	......	......
4	July	7.80	3.81	......	......	......
5	August	7.56	3.42	......	......	......
2	September	8.80	3.87	......	......	......
4	October	9.25	3.86	......	......	......
5	November	9.68	3.50	......	......	......
4	December	7.55	2.96	......	......	......
			1874.			
5	January	6.92	2.68	......	......	......
4	February	7.65	2.83	......	......	......
4	March	6.55	2.77	......	......	......
4	April	6.70	3.38	......	......	......
5	May	7.12	2.94	......	.....	......
2	June	7.70	3.21	......	......	......
4	July	8.50	3.88	......	......	......
5	August	8.28	3.85	0.0147*	......	......
4	September	7.80	3.92	......	......	......
5	October	7.59	3.49	......	......	......
4	November	8.40	3.72	......	......	......
4	December	8.00	3.56	......	......	......
			1875.			
5	January	7.80	3.52	......	......	......
4	February	5.75	2.35	......	......	......
4	March	5.20	2.08	......	......	......
4	April	5.55	2.28	......	......	......
5	May	6.60	3.01	......	......	......
4	June	8.80	3.76	......	......	......
5	July	8.34	3.76	......	......	......
4	August	7.55	3.28	......	......	......
4	September	8.76	3.70	......	......	......
5	October	9.06	3.99	......	......	......
4	November	8.78	4.12	......	......	......
4	December	7.23	3.49	......	......	......
			1876.			
5	January	7.34	3.72	......	0.296*	......
4	February	7.09	3.89	......	0.246	......
4	March	6.17	2.55	......	0.271	......
5	April	5.43	2.24	......	0.186	......
4	May	6.42	2.89	......	0.161	......
4	June	7.30	3.36	......	0.172*	......
5	July	7.39	3.38	......	0.170†	......
4	August	7.56	3.12	......	0.165	......
5	September	6.68	2.94	......	0.189	......
4	October	7.07	3.14	......	0.200	......
4	November	7.67	3.69	......	0.182*	......
5	December	8.67	3.69	......	0.261*	......

No. of Results.	Month.	Total solids.	Hardness.	Albuminoid ammonia.	Chlorine.	Combined nitrogen.
			1877.			
4	January.........	7.94	3.81	......	0.244‡	......
4	February........	7.56	3.38	......	......	......
5	March...........	6.08	3.03	......	......	......
4	April............	6.05	2.86	......	......	......
4	May..............	6.70	3.22	......	......	......
5	June.............	8.24	3.76	......	......	......
4	July.............	7.98	3.70	......	......	......
	August..........	7.98	3.67	......	......	......
5	September.......	7.75	3.53	......	......	......
4	October..........	8.75	2.93	......	......	......
4	November.......	7.52	2.75	0.0156‡	......	......
5	December........	6.82	2.68	0.0092‡	......	......
			1878.			
4	January.........	7.05	2.94	0.0053‡	0.295‡	......
4	February........	6.39	2.43	......	......	......
5	March...........	5.82	2.20	......	......	......
4	April............	6.33	2.36	......	......	......
3	May..............	6.87	2.66	......	......	......
5	June.............	7.13	2.97	......	......	......
4	July.............	7.31	3.68	......	......	......
5	August..........	8.56	3.30	......	......	......
4	September.......	7.97	3.07	......	......	......
4	October..........	8.50	3.22	......	......	......
5	November.......	7.98	3.14	0.0130‡	......	......
4	December...	6.29	2.73	......	......	......
			1879.			
4	January.........	7.36	2.92	......	......	......
4	February........	6.46	2.88	......	......	......
5	March...........	6.11	2.72	......	......	......
4	April............	5.78	2.54	0.0095‡	0.295‡	......
5	May..............	6.57	3.18	......	0.213‡	......
1	July.............	....	....	0.0080	......	......
			1880.			
1	December........	....	....	0.0086	......	......
			1881.			
7	April............	6.87	....	0.0115§	......	......
1	May..............	....	....	0.0070	......	......
1	July.............	....	....	......	......	0.0198
1	November.......	6.90	2.32	0.0140	0.212	0.0181
			1882.			
2	June........... .	....	....	0.0142	......	0.0217
1	July.............	....	....	0.0165	......	0.0163¶
1	August..........	....	....	......	......	0.0330
1	October....	....	....	0.0122	......	......
1	December........	8.80	3.05	0.0092	0.207	0.0192
			1883.			
1	June.............	8.60	2.97	0.0080	0.176	0.0173
			1884.			
5	September.......	8.30	4.02	0.0243	0.182	0.0442
2	December........	8.55	4.99‡	0.0125	0.316	0.0572
			1885.			
1	April............	11.00	4.73	0.0090	0.278	0.0403
2	May..............	6.50	4.18	0.0126	0.296	0.0417
2	June.............	7.25	4.41	0.0105	0.287	0.0420
2	July.............	6.50	4.30	0.0095	0.252	0 0388
2	August..........	7.25	4.46	0.0115	0.296	0.0478
2	September.......	6.50	4.52	0.0127	0.208	0.0424
4	October..........	7.50	4.52¶	0.0148	0.262	0.0468
1	November.......	7.00	3.84	0.0140	0.312	0.0480
1	December........	....	3.73	......	0.295	......
			1886.			
3	January.........	6.50¶	3.41	0.0076	0.301	0.0440
1	February........	7.00	2.94	0.0060	0.381	0.0530
2	March...........	....	2.55	0 0040	0.243	0.0460
	April............	7.15	3.42	0.0095	0.304	0.0510
	May..............	6.94	3.21	0.0067	0.242	0 0457
	June.............	9.50	3.93	0.0054	0.308	0.0483

No. of Results.	Month.	Total solids.	Hardness.	Albuminoid ammonia.	Chlorine.	Combined nitrogen.
			1887.			
2	August..........	9.25	4.50	0.0055	0.230	0.0485
2	September.......	6.75	4.05	0.0115	0 212	0.0430
1	December........	9.00	....	......	0.197	......
			1888.			
3	January.........	5.87	3.39	0.0047	0.239	0.0483
5	February........	6.14	2.99	0.0056	0.227	0 0584
4	March......... .	5.51	2.90	0.0115	0.194	0.0796
4	April	5 68	2.89	0.0124	0.190	0.0642
5	May...............	6.52	3.70	0.0097	0.208	0.0484
4	June.............	7.28	4.65	0.0116	0.181	0.0432
4	July..............	7.35	4.69	0.0061	0.202	0.0392
5	August..........	7.28	4.32	0.0086	0.199	0.0326
4	September.......	.25	3.84	0.0096	0.195	0.0356
5	October..........	7.07	3.59	0.0058	0.185	0.0294
4	November.......	7.98	4.06	0.0062	0.211	0.0390
4	December........	7.15	3.68	0.0035	0.210	0.0432

* Average of 3 results. † Average of 4 results. ‡ One result. § Average of 12 results. ¶ Average of 2 results.

These monthly averages are plotted on the plates accompanying. The scale of total solids and hardness is that given on the left of the plates. That of albuminoid ammonia is multiplied by 100, that of chlorine by 10, and that of combined nitrogen by 100, so that they may be represented by the same. The form of the curves sugges ed to me the possibility that the fluctuations in the quantities depended upon the amount of rainfall or upon the amount of flow of water, The monthly results for each of these items are published in the New Croton Aqueduct Commissioners' Report, 1883–7. Mr. George W. Birdsall, C. E., Chief Engineer of the Croton Aqueduct, has kindly furnished me with the results for 1887 and 1888. The tables are also published in my Report to the State Board of Health, pages 8 to 11. I append the annual summaries, thinking the whole table too long to reproduce in this paper. One particular reason for reproducing the summaries is to call attention to the enormous increase in rainfall and flow of river in the years 1887 and 1888, to which attention will again be called in discussing the curves plotted on the plate.

FLOW OF CROTON RIVER AND RAINFALL ON WATER-SHED.

Year.	Flow of river, in gallons.	Flow of river, in inches over entire water-shed.	Rainfall in inches.	Flow of river in per cent. of rainfall.
1870......	127,198,225,000	21.38	44.63	48
1871......	126,081,752,000	21.19	48.94	43
1872......	114,179,135,000	19.19	40.74	47
1873......	165,841,078,000	27.88	43.87	64
1874......	159,739,632,000	26.85	42.37	63
1875......	164,588,505,000	27.67	43.66	63
1876......	148,106,829,000	24.89	40.68	61
1877......	132,244,815,000	22.23	46.03	48
1878......	171,676,658,000	28.86	54.14	53
1879......	136,028,615,000	22.87	46.08	50
1880......	91,117,423,000	15.32	38.52	40
1881......	119,926,645,000	20.16	46.33	44
1882......	150,833,641,000	25.35	55.20	46
1883......	94,876,593,000	15.95	43.15	37
1884......	151,180,907,000	25.41	53.71	47
1885......	115,903,402,000	19.48	45.99	42
1886......	132,294,573,000	22.24	47.59	47
1887......	167,826,000,000	28.38	61.63	46
1888......	224,943,000,000	37.81	63.51	59

The monthly results for flow of water and for rainfall are plotted on Plate I. The scale for rainfall is that at the left. The results for flow of river are divided by 10,000,000,000, so as to be represented by the same. An examination of the various curves drawn through the plotted points will show their interdependence. To show in other ways the extent of this interdependence, I have plotted curves of yearly averages of the results for each constituent of the water, and corresponding curves for flow of water, using for this latter curve in each case only such months in each year as have results for the constituent of the water under comparison. I have also plotted a series of curves showing the averages for each month during the whole series of years, using the same method of constructing the curve for flow of water as before. These curves are given on Plate II.

It should be distinctly understood that the number of results upon which some of the points in these latter curves depend is too small, and they are too much scattered for their indications to carry much weight. They are given for what they are worth. An examination of the table accompanying, from which the main curves are plotted, will show the necessity for this caution.

Bearing this in mind, it may be said that the curves present the following indications:

Total Solids.—It is quite evident from all the curves that there is a close connection between the amount of "total solids" and the flow of water, the amount of solids decreasing as the amount of water increases. The curves of yearly averages show no marked increase or decrease with time of this impurity, the fluctuations with amount of flow of water being sufficient to conceal any slight change there may be. It should be remarked that the amount of rainfall and flow of water in 1887 and 1888 is one-fourth to two-thirds greater than the average for the 17 years preceding, so that an appreciable decrease in total solids in the latter year is observed, and that this decrease should, therefore, not be attributed to improvement in the purity of the water.

Hardness seems to follow closely the same rule as total solids. However, the indications of the curve of yearly averages are that there has been an appreciable increase in hardness with the time.

Albuminoid Ammonia.—I am unable to recognize any connection between these curves and those of flow of water or of rainfall, the results prior to 1885 being insufficient in number to give a basis on which to form any opinion. The curve of monthly averages for the whole series of years indicates some such variation with the season as might be anticipated if albuminoid ammonia is taken to be an indication of vegetable pollution, the amount being greatest in the fall months of the year, when there is most decay of vegetable matter, and generally full opportunity for such matter to reach the streams through winds and rains. It should be remarked that Wanklyn, one of the originators of the ammonia process of estimating organic pollution of water, utterly condemns any water which contains over 0.015 part in 100,000 of albuminoid ammonia, and considers a water containing over 0.010 part as suspicious. It will be observed that a large part of the results given in the table are above 0.010 and a few are above 0.015. The wholesomeness of the water

cannot be successfully attacked in this manner, however, for waters known to have none but harmless vegetable pollution sometimes far exceed the above results. Allowances for such harmless matters must be made in each locality, and no hard and fast standard of purity can be laid down to be applied indiscriminately. The comparison of numerous analyses of a water at different times should be made to determine, not the absolute impurity in the water, but the increase or decrease in the amount of such impurity. The number of results in our case for albuminoid ammonia are insufficient to justify any conclusion as to increase or decrease of pollution.

Chlorine again has some dependence upon the flow of water, the increase in this case being with the increase in amount of flow of water, and the decrease with a corresponding decrease in the curve of flow. The connection between the two curves is not so close as in the first two. The conformity of the chlorine curve to the curve of flow of water seems to be disturbed in some places by the curve of rainfall. This may possibly be explained in the following manner: A heavy rainfall washes the earth thoroughly and sweeps into the streams a larger amount of organic impurity than ordinarily reaches them, a quantity enough larger to increase the relative as well as the absolute impurity. Should the upper reservoirs of the system of water supply not be full, a portion of this rainfall will be used in filling these reservoirs, and so will not show in the flow of water at the Croton dam, while the amount of chlorine in the water flowing at the dam will be increased. The connection, even with this explanation, is not always close in the curves of monthly averages, nor in the curves of monthly averages for the series of years. It is closer in the curve of yearly averages, except for the drop at the end. It is suggested that this drop may be due to the enormous rainfall of the years 1887 and 1888, having washed the ground comparatively clean and kept it so. The caution respecting paucity of results for many points in the two latter curves is repeated.

Combined Nitrogen.—We have quite a close connection between this curve and that of flow of water, the increases and decreases being nearly always simultaneous in the two curves. A considerable increase in nitrogen with time is indicated, but there is a corresponding increase in flow of water of nearly as great a proportional amount, so that the actual increase in pollution with time is probably small. There is possibly some such variation with the season as was indicated for albuminoid ammonia, but it is pretty well covered up by the greater variation with flow of water. There are but few results on which to base this curve except for the years 1885–6 and 1888.

The general conclusion to be drawn from all the curves is to the effect that the chemical analyses show very little, if any, increase in pollution of the Croton water supply. When the meagreness of results for all the the items given, except total solids and hardness, is considered, and the abnormal rainfall and flow of water in 1887 and 1888, in which latter year the only complete series of analyses for a calendar year is presented, I think it can be safely asserted that the case for or against the Croton water as depending upon chemical analyses, must be put in the category of "not proven" and that further data must be obtained before any

opinion as to the comparative purity of the water can be advanced upon their authority. Such data will be available in the future if the present policy of the City Health Department is carried out. The present system was begun in January, 1888, and consists of a complete analysis of the water as to its organic impurities each week, with daily estimations of chlorine, organic and mineral matters and total solids.

II. Testimony as to the actual fact of pollution entering the streams tributary to the Croton Aqueduct is offered by a report on an inspection of the Croton water-shed, made by Alfred Lucas to Cyrus Edson, M. D., Chief Inspector of the city Health Department, in 1885. A tabular statement of the results in that report is printed in my own report to the State Board of Health, pages 18 to 46. The following summary will show his estimate of the number of sources of actual pollution to the water supply at that time :

No. of houses and privy vaults	1,879	Cider mills	3
Barns and barnyards	602	Iron mines	2
Cows	9,438	Carriage factories	3
Horses	1,284	Slaughter houses	1
Pigs	1,501	Condensed milk factories	1
Sheep	20	Tanneries	1
Saw and grist mills	30	Cement factories	1
Cemeteries	5	Woolen mills	1
Blacksmith shops	19	Machine shops	1

Additional information of this character was obtained by myself in making an inspection for the State Board of Health. Assisted by Prof. A. E. Phillips, of Lafayette, Ind., a Member of this Club, I spent July, August and September of last year in the field work. Mr. Emil Kuichling, C. E., was Consulting Engineer. Our plan of operations was to traverse the whole country with such maps in hand as were obtainable, and to locate upon such maps the streams and the sources of pollution to those streams. At the same time all houses and outbuildings of whatever description were located upon the maps, and an idea was obtained of the character of the rocks and soil, of the slopes, and of the ease with which offensive matters could reach the streams or ground water unpurified, under the various conditions of soil and slope, all to obtain a basis upon which to form an estimate of the distances from streams and water courses to which it would be necessary to remove the drainage of houses and other buildings to insure the practical purification of the same before it reaches the streams. More detailed inspections of villages and hamlets were made, as the amount of possible pollution in a given space is here much increased, and the locations are made upon sketches of larger scale. The villages were also studied with reference to their adaptability to the various systems of sewage disposal that are in vogue, in case it is deemed safest and most economical to dispose of the village wastes as a whole. The sources of general pollution, such as vegetation in streams, swamps, reservoirs, etc., manured fields, roads and streets received their share of attention. About 75 or 80 photographs of sources of actual pollution were obtained, and also a series showing the character of the bed and banks of the proposed new Quaker Bridge reservoir. These photographs give samples of the character of the pollution to which the water is subject. It would evidently be impracticable to show in this manner any very appreciable percentage of the whole number. This informa-

tion, with the addition of that in the report of Mr. Lucas and in that of Professor Waller on chemical analyses, with reproductions of 65 of the photographs, and a chapter of recommendations and suggestions, constitute my report to the State Board of Health, a copy of which is presented herewith for your inspection.

The following table gives a numerical summary of the results of my inspection:

Total number of houses on water-shed	5,056
outbuildings on water-shed	5,612
houses requiring special attention (*i. e.*, draining directly into water)	2.843
outbuildings requiring special attention	3,293
cemeteries	83

Of these the following numbers are in villages :

Total number of houses in villages	2,136
outbuildings in villages	1,406
houses in villages requiring special attention	1,033
outbuildings in villages requiring special attention	821
cemeteries in villages	28

When the greater density of population in some of the villages is considered, it would seem probable that almost every house in a village would be a source of more or less direct pollution to the ground water or the streams, and should be brought under the provisions for the removal of organic wastes from the premises. In the above table the numbers requiring special attention are only those which are evident sources of direct pollution.

I append a description of the village of Brewster, and descriptions of Plates LIII and LIV as a sample of the methods of treatment.*

Brewster is the largest village on the water-shed. While but little larger than what has been included in Mount Kisco in Table IV, it is more compactly built, and is more of a manufacturing and business place, so that it is a much greater source of pollution to the Croton water than any other village. Mr. Lucas' report, pages 27 and 28, gives details of many of the sources of direct pollution. The sketch on Plate IV shows these, and others, and also shows by the contour lines the general course of the surface drainage. Photograph B 1, Plate LXI, shows the drainage of a slaughter house near Tonetta Brook, above Brewster, beyond the limits of the sketch. B 2 to B 4, Plates L to LII, together give a view of the village and a prolongation of it to the southwest down the river. B 5 to B 10, part of which are reproduced in Plates LIII to LVII, give details of special sources of pollution. The surface drainage from the principal part of the village runs almost directly into Tonetta brook, and is a source of much pollution to that brook. The sewers which enter the brook under the main street are an additional source of concentrated pollution, since the supply of water to the sewers is quite small. The soil seems to be quite as open here as elsewhere, so that the drainage from it is daily increasing in richness. I think it probable that as good a plan as any for treating this village is to supply it with a complete system of sewers, for which its topography well adapts it. As indicated above, there has been something done in this line already. There are two or three places where the liquid sewage can be disposed of on the land as suggested on page 154, and will be efficiently purified before entering the water-

* None of the plates here referred to are reproduced in the *Journal*.

courses, all below the level of the village, so that the sewage need not be pumped. These are all near the river, so that very great care should be taken in maintaining the disposal works. It may be deemed advisable to divide the sewer system into two or three parts, and run part of it on each of two or three plots of ground. The proposition discussed on page 156 would locate a garbage and refuse destructor near the intersections of the three railroads, at the northern end of the village, to which all refuse from the villages on those railroads would be carried. If such a destructor is erected it may be found to be more economical to use some method of dry removal in this village, the refuse being carried directly the destructor. The village of Southeast Centre is but a short distance to the east of Brewster, and it will be worth while to discuss the two villages together in determining upon a sewerage system. One advantage of a water-carriage system in these villages, as in the cases of Carmel and Lake Mahopac, will be that by a proper arrangement it may be possible to run a portion of the earlier street drainage, in case of a rain-storm or of the melting of snow in the spring, into the sewers, and thus obtain a purification of this water, which is certainly in a high degree polluted with animal matter.

Plate LIII, Brewster, 5.—A view of the rear of the buildings shown in 3. The East Branch runs, as shown, from left to right, under the foot-bridge seen in the centre. This shows the proximity of the houses, barns, privies, and so forth, to the river. The field in the fore-ground with the barn at the left is subject to overflow by floods. There seem to have been no precautions taken to prevent organic wastes from reaching the river, and in some cases there is even a utilization of the stream for carrying off such wastes. Two, 3 and 4 were taken from a point about half-way up the slope on the extreme right of this picture. Located on Plate I.

Plate LIV, Brewster, 7.—Is a view taken in the culvert which conveys Tonetta Brook under the main street of the village. The culvert turns quite an angle and the view is taken looking up stream from a point just within its lower end. In the large black hole at the left of the centre are the outlets of two sewers which seem to come from the directions of the two branches of the main street, one coming from the east and the other from the north. At the top of the right wall of the culvert, at the right of the centre, is seen a small pipe, egg-shaped in cross section, which is the outlet to a third sewer. A little to the right of this is seen a slimy deposit upon the wall, which indicates the outlet of a drain from water-closets in the bank building which stands just above, in the middle of the space formed by the street intersections, as shown in the sketch of the village, Plate IV. The last two mentioned are in active use, as was demonstrated to us while taking the photograph. The first two are those described by Mr. Lucas in his report, item 215 of Table III. All are sources of organic pollution, in the form principally of human excrement, and their discharge into the stream should be strictly prohibited. Located on Plate IV, sketch of Brewster.

I also give the suggestions referred to in the above description of Brewster as to disposal of sewage.

Bd. Independent Sewerage for Villages.—There are four principal

sources of organic pollution from villages, (1) the human excrement; (2) animal excrement; (3) garbage; (4) street and area sweepings and dirt. The first, second and possibly the fourth, can be removed by a system of water carriage. The second would probably not be so removed from choice, owing to the desire to use it as a fertilizer, and the third could not be so removed.

Should all three or the first and fourth be removed by water carriage, a "combined" system of sewers would be required, admitting to the sewers surface drainage as well as house sewage. This sewage could not be permitted to enter the water-courses without purification. To take care of the water flowing from the sewers in times of heavy rain, sewage treatment works of comparatively large size, or large storage tanks would be necessary, and the sewage would be at times very dilute. Should storm-water overflows be provided, a certain amount of sewage, small in proportion to the amount of water flowing, but still almost the whole amount from the village during the time of action of the overflow, would flow into the streams. This would not be permissible in the present case.

Should a "separate" system of sewerage be decided upon for a village, sewage-disposal works upon a much smaller scale would be necessary. The treatment of street drainage would then be a problem by itself, and it might be possible in such case to secure the earlier washings of the streets during storms for purification, and allow the later, less defiled portions, to escape into the water-courses. Where the roadways are paved or improved, this part of the problem might be rendered easier to solve by removing the street dirt by dry removal with the garbage, leaving but a small proportion of it to be treated in the drainage water.

Of the systems of sewage disposal there are many varieties, which may be gathered into three general classes—the chemical treatment to produce a clarified effluent; filtration, constant or intermittent, through natural or artificial filters, and irrigation on or under the surface.

It is believed that no chemical treatment yet devised will give an effluent sufficiently purified to be at all times absolutely safe for admixture with drinking water. It will, therefore, in general, be necessary to use some one of the other methods of purification mentioned, as an adjunct to the chemical treatment. The sludge precipitated from the sewage in the chemical treatment must necessarily be completely deodorized to prevent nuisance, and should then be removed. Its use upon land in the immediate vicinity of water-courses, or in large quantities simply upon the surface of the land without being incorporated therewith, should be prohibited. Since its value as a fertilizer is very small, it will be well to destroy it entirely. This may be done by drying it or mixing it with some combustible material to increase its consistency, when it may be carried to the garbage destructor suggested in the following article on dry removal systems, and there consumed.

Filtration of sewage through natural or artificial media properly requires a previous sedimentation and straining out of the solids, together with their deodorization, in order to prevent nuisance arising from the filter beds. This can be best attained by some chemical process and its adjuncts. There are many systems of filtration, from the most elaborate

artificial filter to a simple bed formed of natural soil. Most of the methods require intermittent action, at least to the extent of changing filters for purposes of cleaning. For the efficient filtration of the liquid through the earth, intermittence of action is absolutely indispensable. For any system chosen, the requirements are freedom from obnoxious odors and purity of effluent.

Irrigation, whether broad or sub-surface, also requires the removal of solids from the sewage to prevent nuisance, or to prevent clogging of the sub-surface pipes. Greater areas of land will be necessary for the application of the system of broad irrigation than of that of filtration, owing to the necessity of caring for the growing crops. The system of sub-surface irrigation seems to work fairly well, with proper attention, for small amounts of sewage. Larger amounts should probably be divided and run into several small plots rather than into one large one. Systems of intermittent filtration through land and of broad irrigation will require special attention in the winter season. Thorough chemical treatment to give as pure an effluent as possible will then be necessary to prevent nuisance. It is believed that in most cases, and in the weather of most winters, there will be but little, if any, trouble found in running the clarified effluent over the land as usual, if great pains are taken during the cold season to procure as pure an effluent from the precipitation works as possible. However, there is always a risk of nuisance arising from defects, more or less temporary, in the working of the system during the cold season.

Should the street drainage be collected as a whole, or only its more polluted portions, it could be run through similar processes to those above described. Should no system of street cleaning and dry removal of the refuse be adopted some method of purification would generally be necessary. It would be best to adopt one in any case.

Be. Dry Removal. Of the four principal sources of organic pollution from villages, mentioned above, the garbage must be treated by a system of dry removal, and all four may be. The systems of dry removal may be classed as (1) the pail system, including in this term all methods of removal by the use of portable receptacles; and (2) the pneumatic systems. The requirements in any case are freedom from nuisance, both in use and in removal, thoroughness and completeness. It is probable that some pail system will be found to be the cheapest and in many respects the most satisfactory in nearly all cases. It is hard to see how any other method can be applied in some instances. A thorough system, carefully conducted with the above requirements in mind, is what is necessary. Such systems of various forms are in existence of all grades of performance of the duty desired of them.

The disposal of the collections of human and animal excrement, garbage and street dirt, as well as of the sludge from the chemical treatment of sewage, is a serious problem, for which the following solution is offered. Nearly all the villages on the water-shed—all that should have a system of removal of wastes extended over their whole area—are situated on the railroads, of which there are three, the Harlem division of the New York Central & Hudson River Railroad, with Mt. Kisco, Bedford Station, Katonah, Golden's Bridge, Purdys, Croton Falls,

Brewster, Dykeman, Towners, Patterson and Pawling on its main line, and Somers Centre and Lake Mahopac on its Mahopac branch, and Somers but a short distance away; the New York & Northern Railroad, with Mertens, Kitchawan, Croton Lake, Yorktown, Amawalk, West Somers, Baldwin Place, Lake Mahopac, Crafts, Carmel, Tilly Foster and Brewster on its main line, and Mahopac Falls and Mahopac Mines on its Mahopac Mines branch; andthe New York & New England Railroad, with Reynoldsville, Towners, Dykeman, Brewster and Southeast Centre on its main line. These lines all converge in the northern part of the village of Brewster. It would be easy to locate a crematory or garbage destructor near this point, and to transport the solid refuse and the semi-solid refuse after admixture with suitable other matter to give it proper consistency, by means of cars from the various villages to such destructor. One central furnace can thus be made to do the work for practically all the villages, and an economical solution of the problem is thereby offered. The amount of material to be thus disposed of can be approximately estimated by a consideration of the various villages, and it will be found that the expense of transportation and combustion will be a comparatively small proportion of the cost. In some places it would be quite difficult to dispose of the solid refuse in any way except by burning, without danger of nuisance or of pollution of the water, and in all cases it would be necessary to exercise extreme care to obviate these dangers.

Should the animal excrement in villages not be removed at frequent intervals by any of the methods suggested, but be preserved for use as a fertilizer, strict supervision should be exercised over its manner of keeping to see that none of it, nor any drainage from it, reaches the water-courses unpurified.

III. Under the laws of the State of New York the State Board of Health is authorized to make rules for the preservation of the purity of the water supply of any city or town, which rules shall have the force of law. Last June the Mayor of the City of New York requested the State Board of Health to make such rules for the water-sheds from which that city draws its supply. My inspection was made to obtain detailed information upon which to intelligently proceed to the framing of such rules. I abridge from the report of the State Board the following as the shortest statement of the principle of procedure.

The general principle upon which we have proceeded in framing the accompanying rules is as follows:

"*First.* The establishment of a marginal zone around every lake, pond or reservoir adjacent to every spring, stream or natural water-course of any kind on the entire water-shed of the Croton River, and on those portions of the water-sheds of the Bronx and Byram rivers now used for the water supply of the city of New York. The width of said zone adjacent to the lakes, ponds and reservoirs has been taken at fifty feet; while for that adjacent to the tributaries the nominal distance of thirty feet has been prescribed. From these zones it is the purpose of the rules to exclude all kinds of contamination upon or below the surface of the ground.

"*Second.* Recognizing the fact that many habitations and vested interests

are adjacent to the lakes, ponds and reservoirs and their tributaries, which must be considered, a second zone has been established adjacent to the first named which is 200 feet wide around lakes, ponds or reservoirs, and 100 feet wide around or along tributaries. Within this zone it is the intention to prevent defilement of the surface soil and the subsoil; and to this end restrictions as to the manner of maintaining sources of actual or possible pollution have been made. The restrictions are based upon the fundamental principle that the accidental deposit of solid organic wastes must be retained upon the surface of the ground or transferred by natural agencies over such distance as will render their entrance into the waters highly improbable. While the State Board of Health, in establishing these limits for filtration or percolation of sewage through soil, does not fix the same as absolutely safe under all circumstances, yet, in considering the general topographical and geological characteristics of the water-sheds lying in the counties of Westchester, Putnam and Dutchess, it is thought that such limits will afford reasonable guarantee of the resulting discharge being safe when not in too large volume. To provide for every conceivable condition is manifestly impossible, and hence only general rules can be formulated. When the rock or other impervious stratum is covered only by a thin layer of very porous material, like gravel, or when the entire subsoil is formed of such material, this distance must obviously be increased. On the other hand, when, owing to the topographical peculiarities, it is impossible to comply with the strict provisions of the above rules, proper modification may be permitted by the substitution of such devices or constructions as shall receive the special approval of the State Board of Health.

"With reference to the tributaries to lakes, ponds and reservoirs, the limit in which restrictions have been imposed have been taken somewhat smaller than in the case of the larger bodies of water, in view of the fact, that before such polluted matter can reach the reservoirs or ponds from which the supply is taken, it is probable, that certain purification will have been accomplished by flow through a greater or less length in open water-courses, and by the exposure of such matter to the modifying or destroying influences therein contained.

"While the rules do not enumerate all possible sources of pollution, or even all those which have been specified in the engineering report, it has not been thought expedient to encumber them with a multitude of details, the execution of which would, in all probability, be performed by aqueduct commissioners or their agents spontaneously. In this class of details may be placed the drainage and improvement or exclusion of swamps, bogs and marshes, and the removal of improper surface vegetation, the excavation of shallow places in the reservoir, the removal of deposits and shoals more or less impregnated with organic matter that have accumulated at the mouths of the tributaries of the various lakes, ponds and reservoirs; the location and construction of roads and highways in such a manner that the drainage waters therefrom shall be insured a reasonable degree of purification by flow through or over the surface of the land before reaching the principal water-courses or stored waters."

The following is the series of rules adopted. Similar, but less elabor-

ate sets of rules are in operation on the water-sheds of the water supplies of several towns and cities in the State.

RULES AND REGULATIONS.

Privies Adjacent to Lakes, Ponds or Reservoirs, and Water-Courses.

First.—No privy, or place for the deposit or storage of human excreta shall be constructed, located or maintained within 50 feet, horizontal measurement, of the high-water mark of any lake, pond or reservoir, or within 30 feet, horizontal measurement, of the high-water mark or precipitous bank of any spring, stream or water-course of any kind, tributary to said lakes, ponds or reservoirs on the entire water-shed of the Croton River, or on those portions of the water-sheds of the Bronx and Byram rivers now used for the water supply of the city of New York.

Second.—No privy vault, pit or cesspool, or non-transportable receptable of any kind for the reception or storage of human excreta shall be constructed, located or maintained within 250 feet, horizontal measurement, of the high-water mark of any lake, pond or reservoir, or within 130 feet, horizontal measurement, of the high-water mark or the precipitous bank of any spring, stream or water-course of any kind on the entire water-shed of the Croton River, or on those portions of the water-sheds of the Bronx and Byram rivers now used for the water supply of the city of New York.

Third.—Every privy, or place for the deposit of human excreta, which is constructed, located or maintained between the aforesaid limits of 50 feet and 250 feet, horizontal measurement, of the high-water mark of any lake, pond or reservoir, or within the limits of 30 feet and 130 feet, horizontal measurement, of the high-water mark or precipitous bank of any spring, stream or water-course tributary to such lakes, ponds or reservoirs, on the entire water-shed of the Croton River, or on those portions of the water-sheds of the Bronx and Byram rivers now used for the water supply of the city of New York, and from which the said excreta are not at once removed automatically, by means of suitable water-tight pipes or conduits, to some proper place of ultimate disposal, as hereinafter provided, shall be arranged in such manner that all said excreta shall be received and temporarily maintained in suitable vessels or receptacles, which shall at all times be maintained in an absolutely water-tight condition, and which will admit of convenient removal to some place of ultimate disposal, as hereinafter set forth.

Fourth.—Whenever it shall be found that owing to the porous character of the soil, the height and flow of the surface and subsoil waters, the steepness of the slopes, or other special condition of the locality, the excremental matter from any privy, cesspool or other receptacle for human excreta, situated within the limits hereinbefore provided, may be washed over the surface or through the subsoil into any lake, pond or reservoir, or into any spring, stream or water-course tributary to such lake, pond or reservoir on said water-shed of the Croton River, or on those portions of the water-sheds of the Bronx and Byram rivers now used for the water supply of the city of New York, without having been thereby, in the judgment of the State Board of Health, sufficiently purified, then the said privy, cesspool or other receptacle for human excreta shall, after due notice to the owner thereof, be removed to such greater distances from said high-water marks as shall be considered safe and proper by the State Board of Health.

Fifth.—All said receptacles for human excreta must be provided with tightly-fitting covers, which shall be securely applied during the process of removal, so that no portion of the contents of said receptacles shall escape therefrom while being transported from the privy to the place of ultimate disposal.

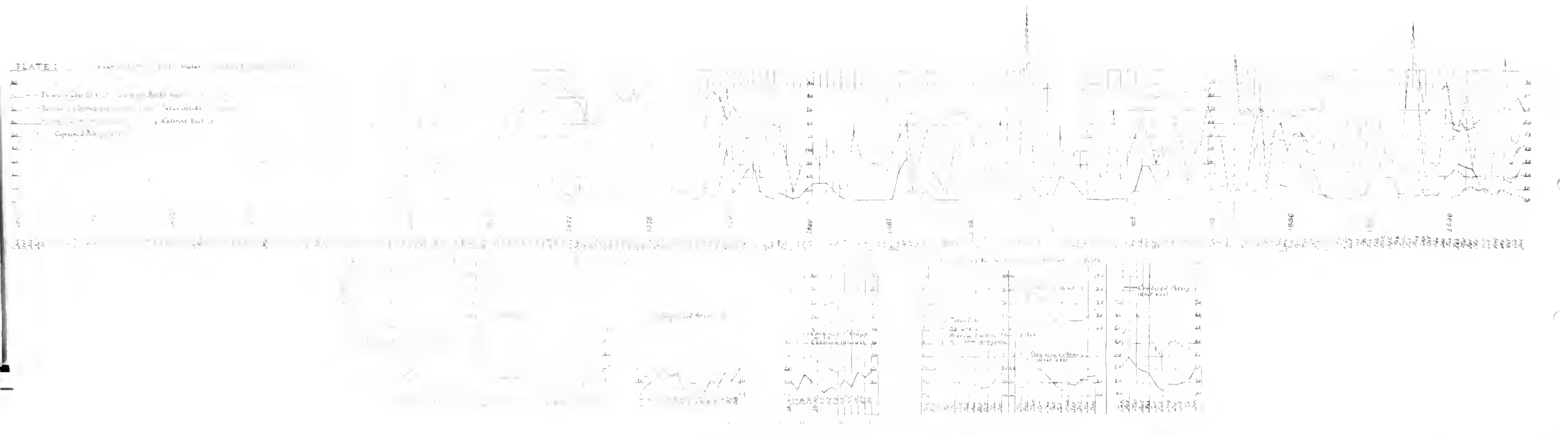
Sixth.—A sufficient number of duplicate receptacles of said general description or character shall be provided, so that when one of the same is removed from the privy an empty receptacle may at once be substituted in its place.

Seventh.—All such receptacles, when filled, shall be removed to some place of ultimate disposal as hereinafter provided, and said receptacles themselves shall be thoroughly cleansed and deodorized as often as may be found necessary to maintain the privy in proper sanitary condition, and to prevent an overflow of the excreta upon the soil or floor of said privy.

Eighth.—The excreta collected in the aforesaid receptacle shall be removed to some convenient place of ultimate disposal, which shall be not less than 250 feet from the high-water mark or precipitous bank of any lake, pond, or reservoir, and not less than 130 feet from the high-water mark or precipitous bank of any stream, spring, or water-course of any kind on the entire water shed of the Croton River, or on those portions of the water-sheds of the Bronx and Byram rivers now used for the water supply of the city of New York, and from which they cannot be directly washed by rain, or melting snow, or otherwise over the surface of the ground into any lake, pond, or reservoir, or into any spring, stream, water-course, channel, or well which is tributary thereto on the entire water-shed of the Croton River, or cn those portions of the water-sheds of the Bronx and Byram rivers now used for the water supply of the city of New York.

Ninth.—In the absence of any other manner of disposal of the excreta collected as aforesaid, which is not specifically approved by the State Board of Health, after due submission to said Board, the said excreta shall be disposed of by digging the same into the surface soil or by burial in trenches of moderate depth in places where the character of the subsoil and the depth of the ground-water level will afford ample security both against the undue pollution of such ground-water and the soil itself, and for the efficient filtration of the liquid contents of the said receptacles.

Tenth.—The removal of the aforesaid receptacles from the privies shall be conducted in such manner as to cause as little inconvenience or annoyance to the occupants of the premises as is compatible with proper management of the work.



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House Slops, Sink Wastes, Laundry Water and other Similar Sewage.

Eleventh.—No sewage, house slops, sink wastes, water in which clothes or bedding have been washed or rinsed, nor any other polluted water or liquid shall be thrown or discharged directly into any lake, pond, or reservoir as aforesaid, or into any spring, stream, or water-course tributary thereto, nor shall any such aforesaid liquid or solid matter or other polluted liquid be thrown or discharged upon the surface of the ground or into the ground below the surface in any manner whereby the same may flow into any lake, pond, or reservoir, or into any spring, stream or water-course tributary thereto within 50 feet, horizontal measurement, of the high-water mark in any lake, pond, or reservoir, or within 30 feet of the high-water mark or the precipitous bank of any spring, stream or water-course tributary to said lakes, ponds, or reservoirs.

Twelfth.—The foregoing rule shall be considered applicable only where the quantity of such polluted water or liquid wastes is small, such as may be derived from a single family; but when relatively large quantities of such wastes are produced and are thrown or discharged upon or below the surface of the ground at any point beyond the aforesaid limits, in such manner or volume as to cause the same to flow over the surface of the ground, or through it below the surface, into any lake, pond or reservoir, or into any spring, stream or water-course tributary thereto, without having been thereby. in the judgment of the State Board of Health, sufficiently purified, then, upon due notice to the owners or occupants of the premises from which such discharge comes, the aforesaid distances shall be increased respectively to such other limits as shall appear justified to said State Board of Health.

Thirteenth.—In case that human excrement is mingled with any of the aforesaid polluted water or other sewage, the discharge of the same upon or below the surface of the ground will be governed by the rule relating to privies.

Fourteenth.—No clothes or unclean objects of any kind shall be washed in any lake, pond or reservoir, or in any spring, stream or water-course tributary thereto.

Garbage and Refuse.

Fifteenth.—No garbage or putrescible refuse of any kind shall be thrown or discharged directly into any lake, pond or reservoir, or into any spring, stream or water-course tributary thereto; nor shall any such substances be placed in large quantities upon or below the surface of the ground where they may be washed into any lake, pond or reservoir, or into any spring, stream or water-course tributary thereto, within 100 feet of the high-water mark in any lake, pond or reservoir, or within 50 feet of the high-water mark or precipitous bank of any spring, stream or water-course tributary to said lakes, ponds or reservoirs.

Sixteenth.—The State Board of Health shall have the right to increase the aforesaid distances in all cases where, in its judgment, it may appear that injury to the purity of the water results from the deposit or storage of garbage or putrescible refuse as aforesaid.

Seventeenth.—Where it becomes impracticable to comply with the foreging rules so far as the disposal of garbage or putrescible refuse upon or below the surface of the ground is concerned, then suitable water-tight receptacles must be provided and be so located and maintained on the premises that none of the contents thereof shall escape and pollute the waters as heretofore indicated.

Manures, Composts and Similar Matter.

Eighteenth.—No stable, pig-sty, hen-house, barn-yard, hog-yard, hitching or standing-place for horses or cattle, or other place where animal manure accumulates, shall be constructed, located or maintained within 100 feet of the high water mark in any lake, pond or reservoir, or within 50 feet of the high-water mark or precipitous bank of any spring, stream or water-course tributary to said lakes, ponds or reservoirs.

Nineteenth.—No stable, pig-sty, hen-house, barn-yard, hog-yard, hitching or standing-place for horses or cattle, or other place where animal manure accumulates, shall be arranged or maintained in such manner that the washings or drainage therefrom may flow through open or covered drains or channels into any pond, lake or reservoir, or into any spring, stream or water-course tributary thereto, without having undergone proper purification.

Twentieth.—The foregoing rules shall also apply to composts and to masses of fermented or decayed fruit, vegetables, roots, grain, sawdust, leaves, or other vegetable substances, which may be used either alone or in a combination with other matter as manure, or as food for domestic animals.

Dead Animals, Vegetable Refuse and Manufacturing Wastes.

Twenty-first.—No dead animal, bird, fowl, fish or reptile, or parts thereof, nor any filthy or decaying matter of animal or vegetable origin derived from human habitations, barns or stables, nor any putrescible matter or waste product or polluted liquid from any slaughter-houses, creameries, condensed milk factories, cheese factories, breweries, distilleries, cider-mills, wine or beer vaults, sugar or glucose factories, tanneries, woolen-mills, paper-mills, pulp-mills. saw-mills or other manufactories, shall be thrown, discharged, drained or washed into any lake, pond or reservoir, or into any spring, stream or water-course tributary thereto.

Twenty-second.—No dead animal, bird, fish, fowl or reptile, or any part thereof, shall be buried in the ground within 250 feet of the high-water mark of any lake, pond or reservoir, or within 130 feet of the high-water mark or precipitous bank of any spring, stream or water-course tributary thereto.

Twenty-third.—No live sheep or other animal shall be washed in any lake, pond or reservoir, or in any spring, stream or water-course tributary thereto; neither shall any person swim, bathe or wash in any of said lakes, ponds or reservoirs, or in the streams tributary thereto.

Twenty-fourth.—The waste liquids which may be polluted with putrescible or deleterious organic matter from any of the operations above indicated shall all be thoroughly filtered or otherwise purified before being allowed to escape into any lake, pond or reservoir, or into any spring, stream or water-course tributary thereto.

Cemeteries.

Twenty-fifth.—No interment shall be made in any cemetery or other place of burial on the entire water-shed of the Croton River, or on those portions of the water-sheds of the Bronx and Byram rivers now used for the water supply of the city of New York, within 250 feet, horizontal measurement, of the high-water mark in any lake, pond or reservoir, or within 130 feet, horizontal measurement, of the high-water mark or precipitous bank of any spring, stream or water-course tributary to such lakes, ponds or reservoirs.

Twenty-sixth.—Whenever it shall be brought to the notice of the State Board of Health that, owing to the porous character of the soil, the height and flow of the sub-soil waters, the steepness of the slopes or other special conditions of the locality, the percolation or drainage from any cemetery or place of burial is polluting the waters of any lake, pond or reservoir, or of any spring, stream or water-course tributary thereto, the aforesaid limits within which interments are not permitted shall be extended as much further from said high-water marks as shall be considered safe and proper by the State Board of Health.

Provision for Appeals to State Board of Health.

Twenty-seventh.—Wherever any system of treating excremental matter from any dwelling, hotel, stable, factory or other building from which such matter may be discharged, by means of sub-surface irrigation, filtration, chemical process or otherwise, has already been established, and now discharges the effluent liquid or solid matter anywhere within 250 feet, horizontal measurement, of the high-water mark in any lake, pond or reservoir, or within 130 feet, horizontal measurement, of the high-water mark or precipitous bank of any spring, stream or water-course tributary to such lakes, ponds or reservoirs on said water-sheds, such discharge shall no longer be permitted, but must be carried to some suitable point beyond said limits respectively, unless especially allowed by the State Board of Health.

Twenty-eighth.—Wherever any system of treating house-slops, sink-wastes, laundry-water, stable drainage, factory wastes or refuse, garbage, or any other putrescible waste matter or the drainage therefrom, by means of sub-surface irrigation, filtration, chemical process or otherwise, has already been established and now discharges the effluent liquid or solid matter anywhere within 50 feet, horizontal measurement, of the high-water mark in any lake, pond, or reservoir, or within 30 feet, horizontal measurement, of the high-water mark or precipitous bank of any tributary spring, stream or water-course, such discharge shall no longer be permitted, but must be carried to some suitable point beyond said limits respectively, unless specially allowed by the State Board of Health.

Penalty.

In accordance with Section 2 of Chapter 543 of the Laws of 1885, a penalty of not less than fifty nor more than one hundred dollars is hereby imposed upon any corporation, person or persons guilty of a violation of, or non-compliance with any of the above given mandatory rules or regulations, to be recovered under said act.

At a special meeting of the State Board of Health, held on the 15th of March, 1889, at the Capitol, in the city of Albany, the foregoing rules and regulations were made, ordained and established, pursuant to Chapter 543 of the Laws of 1885, for the protection of the water-shed of the Croton River and its tributaries in the counties of Westchester, Putnam and Dutchess, and of so much of the Bronx and Byram rivers and their tributaries in the County of Westchester as are now used for the supply of water for the City of New York.

Thos. Newbold, President.
Lewis Balch, M. D., Secretary and Executive Officer.

White Plains, N. Y., March 26, 1889.

Pursuant to chapter 543 of the Laws of 1885, as amended by chapter 52 of the Laws of 1888, I, Jackson O. Dykman, a justice of the Supreme Court of the State of New York, in and for the second judicial district, within which district the counties of Westchester, Putnam and Dutchess are situated, do hereby approve of the foregoing rules and regulations, made, ordained and established by the State Board of Health on the 15th day of March, 1889, for the sanitary protection of the Croton River and its tributaries, and so much of the Bronx and Byram rivers as are now used for the supply of water for the city of New York.

J. O. DYKMAN,
Justice Supreme Court.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

JUNE 19, 1889:—A regular meeting was held at the Society's rooms, Boston & Albany Railroad Station, Boston, at 19:30 o'clock—President FitzGerald in the chair—forty-three Members and fourteen visitors present.

The record of the last meeting was read and approved.

Messrs. Charles H. Bartlett, Frank E. Hall, Frederic S. Hunter and Hiram Nevons were elected Members of the Society.

Mr. George L. R. French, Boston, was proposed for membership; recommended by H. Bissell and J. P. Snow.

On motion of Mr. Howe the Secretary was requested to convey to Mr. Hiram F. Mills the thanks of the Society for courtesies received on the occasion of the visit to the experimental station for purification of sewage at Lawrence.

On motion of Professor Allen it was voted to omit the regular meetings of July and August.

The President announced that notice had been received which would require the Society to secure other rooms for its meetings before September next. On motion Mr. Stearns it was voted to refer to the Government, with full powers, the question of procuring other quarters.

Mr. Thomas Doane spoke briefly of a process of vulcanizing wood which had come to his notice, and which seemed to him worthy of investigation.

Mr. F. F. Forbes read a paper entitled "Algæ Growths in Water Supplies," which was discussed by Prof. Thomas M. Drown, of Boston, and Mr. G. W. Rafter, of Rochester, N. Y., and by Messrs. FitzGerald and Stearne, of the Society.

[*Adjourned*]. S. E. TINKHAM, Secretary.

WESTERN SOCIETY OF ENGINEERS.

JUNE 5, 1889 :—The 259th meeting of the Society was held at its rooms, 78 La Salle street, Chicago, Wednesday, June 5, 1889, at 7:30 P. M. President E. L. Corthell in the chair. The minutes of the last meeting were read and approved.

Applications were placed on file from Andrew Onderdonk, Contractor for new water tunnel, Chicago; Max J. L. Towler, Detroit Bridge and Iron Works, Detroit, Mich.; H. Russell Smith, Secretary J. B. Smith & Co.; H. A. Stoltenberg, Department Public Works, Hyde Park, Chicago.

Upon ballot the following were elected Members of the Society: A. S. Bertolet, Edward C. Hammond, W. R. Kellogg, William B. Vetterlein, Charles A. Hasbrouck, Wm. Rufus Northway, Louis R. Cobb, Charles A. Arentz, Robert P. Brown, Daniel W. Maher, De Clermont Dunlap, Alfred G. Riter, Jules E. Roemheld, Augus Ziesing, John F. Wallace, Urban H. Broughton, G. W. G. Ferris, Eugene A. Rudiger, H. L. Bridgman.

The President called for reports of standing and special committees, but none were forthcoming.

The next in order being unfinished business, the vote upon the revised Constitution was taken up. Some of the members present drew attention to several minor details which had been overlooked by the committee, and in all probability by the letter ballots in the Secretary's hands. These were only vital in so far as they militated against the consistency of the Constitution and By-laws as a whole, and their inviolability as regards the business of the Society.

Mr. Cooley explained the changes he thought it desirable to make, and Mr. Strobel also added some suggestions.

In order to place it on record the President called for a vote on the suggestions, as follows:

Art. 3, Sec. 1, of Constitution, to read: "Shall be filled without unnecessary delay at a meeting of the Society." Carried.

Art. 2, Sec. 3, to read: "The officers, including one trustee, shall be elected by ballot at the annual meeting in January." Carried.

Additional Section to Art. 4, No. 6, to read: "Any member who has been a member for 20 years, or upon the payment of $100, may become a life member, in such manner as provided by the By-laws." Carried.

The President appointed Messrs. Cook and Samuels as tellers to count the ballots. The tellers reported 55 ballots cast, all in the affirmative. Revised Constitution and By-laws unanimously adopted.

There being no other business before the Society, the President called for suggestions as to the line of policy to be pursued by the Society in a professional way.

Mr. Cooley then spoke as follows: I have one suggestion, and that is in regard to the reading of technical papers before the Society. I think that nearly every one sees all the technical literature, and, perhaps, more than he cares for. Such papers are very valuable, no doubt, many of them, and should be printed for general circulation, and those who may be specially interested in them will, of course, read them as published by the Society. And I think it is sufficient, unless there be topics in these papers which will call for general discussion, for the Board of Directors, or the Secretary, to read the same, to approve them and forward them for printing, and that the meetings of the Society be devoted to some special topic, which is of interest to engineers and will promote the good of the profession. I have had it very strongly in mind this winter—and I have had it drummed into me for the last two years—the comparative ease with which engineers can produce effects in legislative bodies, and it strikes me that the most useful line in which engineers can work is in securing legislation, National and State, which may be of utility to the profession. I think our inactivity in that respect has largely relegated the profession to the sixth story garrets and back rooms, and if the engineers of the country don't get out and exercise their influence for their own good, there is no body of citizens who will go out and do it for them. I refer especially in this connection to our work in Congress, with which Mr. Corthell is familiar, where a comparatively small body of men, working with rather the luke-warm support of the profession—on one idea which they have steadily pushed —have succeeded in presenting a matter of great moment to the country, and getting favorable reports from both Houses of Congress. The matter has been put in such shape that it is almost the common consent of the people who know of what they speak, that it can be put through. I refer to the reorganization of our National Public Works.

At the beginning of this year the Society had a committee in charge of the drafting of a bridge law. I know, also, some suggestions were made in regard to a law which would empower the State Board of Health of Illinois to require that all drawings and plans for water-works and sewerage should be submitted to the State Board of Health for approval, very much after the manner in which they are submitted to the local Government Board in Great Britain. I think you all will see the utility of these laws, and I am fully persuaded that if a committee of our Society had devoted the necessary time to it at Springfield this winter, that not only these laws, but any others which engineers could support, could have been passed through the legislature. I think these matters should be taken up, and I hope they may be taken up by committees and discussed in the Society with a view to some action which may interest the profession.

A short discussion then ensued as to arrangements of library and access to the rooms at all times, and also as to the procuring of professional periodicals, in all of which progress was made looking to the practical solution of the problems.

The Secretary made some remarks on the questson of topical discussions, and urged that some steps be taken towards providing the subjects.

It was suggested that this was work for the Board of Directors, to which the Secretary took exception, as the questions for discussion should come from the Members of the Society, to be afterwards arranged for discussion by the Board

The President spoke on the subject in the line of securing profitable work for the Society.

Mr. Cooley suggested the invitation of a Member of the Electrical Society to give us an evening on motors.

Mr. Feind, in order to make a beginning in the matter, moved that the Secretary give notice to the Members to send individually a list of questions which they would suggest for discussion. He concluded by saying that the Board of Directors would then have a basis upon which to act.

The motion of Mr. Feind was put to vote and carried.

Mr. Strobel again spoke on the subject of periodicals, which resulted in a motion by Mr. Cooley that the Library Committee prepare a desirable list of periodicals and report at the next meeting.

The meeting adjourned until the first Wednesday in July, unless otherwise considered, of which due notice will be mailed by the Secretary.

JOHN W. WESTON, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

JUNE 15, 1889:—The regular monthly meeting of the Society was held at the office of Mr. Beckler, Chief Engineer of the Montana Central Railway, President B. H. Greene presiding. There were present Messrs. Haven, Herron, Foss, De Lacy, Haire, Sizer, Keerl, and as visitors Hon. T. H. Carter, Wm. C. Child, Wm. T. McFarland and Mr. Burt, of Colorado.

A communication was read from Hon. T. H. Carter, Delegate in Congress, calling the attention of the Society to the fact that a committee of the United States Senate, of which Senator Stewart is chairman, will be in Montana during the month of August for the purpose of investigating the question of canals and storage of water for irrigating purposes, and expressing the belief that this Society could be of very material assistance in furnishing data concerning the engineering points involved, and that he would take pleasure in procuring for the Society all the information he could obtain concerning the irrigation proposition provided the Society will take up the question, with a view to furnishing the Senate Committee with data.

Mr. Carter by request addressed the meeting on the subject. He stated that this matter which had been suggested was of vital interest to the future state of Montana, and that her resources could never be properly husbanded without the accomplishment of a comprehensive system of irrigation. He had been much surprised upon research to learn what a large proportion of the entire earth's surface could be irrigated. He classed the lands of Montana as one-fifth good agricultural. three-fifths grazing land and one-fifth mountainous, and that by judicious husbanding of waters the three-fifths grazing land could be made good agricultural land, and that a part of the one-fifth mountainous could be raised to a high state of cultivation. He pointed to the fact that the great plains of South America were made productive through the canals built by Pizarro, hewn through rocks, that had been productive of reclaiming vast and valuable tracts from the previous classification of deserts. It was but recently that Congress has taken this matter of extensive irrigation up for examination, brought about by the restless spirit of

those seeking new homes. Montana had not received her share of the investigation due her importance, but is now advancing from that position. Mr. Stewart, the Chairman of the Senate Committee, Mr. Carter spoke of as an enthusiast upon the question of irrigation—that upon a visit to his rooms he had found them full of maps, histories and pamphlets without number, all relating to the subject so near his heart, and that he had found the Senator a close student upon the ancient history of irrigation. Mr. Carter said the Senate Committee would want reliable data, and from the manner in which this Society had taken hold of other matters of public interest, he could not think of a better source from which it could be secured. The methods to be employed to obtain the data he would have to leave to the Society, but he would venture some suggestions as to the committee's wants, and leave them for the Society to formulate. He then detailed the specific information desired, and thanked the Society for the interest it had manifested in the subject, and for the privilege of addressing the meeting.

A general discussion followed Mr. Carter's remarks, and he was asked many questions relative to the ultimate intention of Congress in the matter, etc.

Mr. Wm. C. Child, by request, addressed the meeting upon the subject, stating many interesting and important features surrounding the general question.

A vote of thanks was tendered Mr. Carter and Mr. Child for bringing this matter to the attention of the Society.

Upon motion, the Chair appointed the following committee to collate all data obtainable upon the question of irrigation in time for presentation to the Senate Committee upon their arrival, the first six named to constitute a subcommittee:

W. W. de Lacy, Helena; W. A. Haven, Helena; F. L. Sizer, Helena; J. S. Keerl, Helena; G. O. Foss, Helena; E. H. Beckler, Helena; George Scheetz, Miles City; James M. Page, Twin Bridges; C. G. Griffith, Great Falls; H. B. Davis, Deer Lodge; George T. Wickes, Helena; Joseph H. Harper, Butte; E. H. Wilson, Butte; E. A. Crallé, Philipsburg.

The Chairman of the Committee named next Wednesday at 7:30 P. M., at the Surveyor General's office, the time and place for the first meeting.

A communication was read from Mr. E. O. Goodridge stating that his absence from Montana would be continued for some time, and that he desired to withdraw from active membership, as provided by Art. 14, Sec. 5, of the By-Laws. On motion, carried, the withdrawal of Mr. Goodridge from active membership was allowed and his name placed on the list of Associate Members.

Invitations to the officers of the Society from the Board of Directors of the American Society of Civil Engineers to attend the Annual Convention held June 20, 1889, were presented and the Secretary instructed to express to the American Society the thanks and appreciation of this Society for the kind remembrance.

Mr. Keerl, representative in the Board of Managers of the Association of Engineering Societies, reported that he had been advised by Mr. Benezette Williams, Chairman of the Board of Managers, that the vote in the Board upon the first amendment to the Articles of Association was as follows:

For, 8; against, 0; not voting, 3.

A communication from Mr. W. H. Boardman, of the *Railroad Gazette*, was read, relative to a binder for the *Journal* that could be secured at the following price:

One binder, by mail, postage prepaid, 40 cents; awl, for punching holes in magazine, 2 cents; extra for owner's name stamped on cover, 6 cents. A sample of the binder was exhibited, it being of full cloth binding and very neatly finished. The Secretary would suggest that those members who desire this binder should forward their order at once, with price, to Mr. W. H. Boardman, No. 73 Broadway, New York City, as the meeting decided not to order the binders for members, but to leave it to individual choice.

[*Adjourned.*] J. S. KEERL, Secretary.

ASSOCIATION OF ENGINEERING SOCIETIES.

ORGANIZED 1881.

Vol. VIII. August, 1889. No. 8.

This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

STEAM PLANTS FOR ELECTRICAL SERVICE.

BY WM. H. BRYAN, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read April 3, 1889.]

Few industries of modern years have shown the wonderful growth that has characterized the manufacture and use of the various forms of dynamo electric machinery. Less than ten years ago the arc electric light was just becoming known and the incandescent lamp was scarcely more than a curiosity,while the electrical transmission of power was hardly thought of. To-day there are few towns of 3,000 inhabitants but boast their arc or incandescent electric lighting plants, and many smaller places are fully as progressive. In the large towns and cities the great business houses have their own plants, and central stations whose capacities are measured by the thousands of horse power are not uncommon. Add to these the electric railway, which has now demonstrated its success, and we get an idea of the vast possibilities of this field of energy, which is still in its infancy. While many of the earlier stations did not prove as successful financially as was anticipated, the test of continuous and regular service has pointed out the weak places, and they have been remedied. When careful business sagacity and caution are exercised—as they must be in any successful venture—the electrical industries to-day offer excellent returns to the capitalist. Perhaps the best evidence of this lies in the gross capacity of plants now in operation, estimated at 750,000 horse power, and fast nearing one million.

The world waits impatiently for that immortal inventor whose genius shall show us how to produce electricity direct from coal. We must take things as we find them, however. Our boilers and furnaces give back in steam less than 80 per cent. of the energy of the coal burned. This steam does work in a wofully imperfect engine, utilizing less than 15 per cent. of the heat units. This engine, in turn, drives the dynamos by which the electric current is generated. After distribution, the current re-appears in the form of the electric light—there being a further loss of say 10 per cent. in each of the last steps. It is evident, therefore, that in the best plants less than 10 per cent. of the energy in the coal consumed is reproduced in the form of light. The poor plants, which are far more common, do notreach 5 per cent.

And yet within these appallingly low figures there is abundant room for study. The conversion of fuel into electric energy has caused the development of steam plants adapted specially for this service. The business of these stations is, in fact, the selling of power, and the steam plant is therefore of prime importance. It is not too much to say that permanent commercial success is conditional, first of all, upon a properly designed steam plant. Many companies have found, to their sorrow, that a cheap outfit has proved wonderfully costly to operate and maintain. Others have shown that a somewhat higher first cost has been fully justified by reduced expense of operation and greater reliability. The furnishing of electric light and power may now be regarded as a permanent industry, and the installation of plants presents a broad field of usefulness to the engineer.

Too often the selection of the motive power is left to some one wholly inexperienced, who bases his conclusions upon considerations which are far from being the ones of first importance. The results are as might be expected. We see on every hand instances of mistakes which are costing thousands of dollars unnecessarily in fuel bills, repairs, power wasted, etc. Machinery is now built capable of maintaining one horse power one hour on one and one-half pounds of good coal. When we remember that in most plants five to six pounds are required, and instances are not uncommon where it reaches ten and even fifteen, we see that great improvements are possible. The wonder is, not that electric lighting has sometimes proved unremunerative, but that it has ever paid, under such conditions. The inevitable conclusion is that the fierce competition which now exists, and which bids fair to continue, will result in the "survival of the fittest" only. That electrical station which builds its steam plant in strict accordance with the best principles of modern engineering, has already won more than half the battle, and will surely distance the one in which those principles are considered of minor importance.

Some further explanation of the percentages given above may not be out of place. A boiler efficiency of 80 per cent. is the best attainable under ordinary working conditions. The purposes of combustion necessitate a good draft. This is proportional to the difference in temperature between the chimney gases and the outside air. (See formula on page 426). It is, therefore, *necessary* to discharge the gases at a temperature considerably above that of the steam in the boiler.

Nor is the case of the engine as bad as appears at first sight. Its efficiency also is limited by the range of working temperatures. The higher the initial temperature of the steam, and the colder it is when finally discharged, the higher will be the efficiency. This is best shown by the well known formula $E=\frac{T_1-T_3}{T_1}$, where T_1 is the initial and T_3 the final temperature of the steam, both measured from the absolute zero.

Practical conditions, however, confine us to narrow limits. High initial temperatures mean greater pressures, more costly plant, increased liability to accident, and difficulty of maintenance and repairs. The lowest temperatures which can be reached in practice are far above the absolute zero These losses are inherent in the theory of the steam engine, and but little

increase of efficiency is possible. As a matter of fact, that engine which can furnish one horse power with 13 pounds of water evaporated per hour, is very close to the highest that is possible under the best conditions of modern practice.

Economy of fuel, however, is not always the most important consideration. Conditions frequently arise which render a sacrifice of fuel necessary to secure other and more desirable ends. The work required of an electrical station differs in important respects from other plants in public service. Gas and water works have their storage reservoirs, enabling their work to be done under conditions favorable to high economy. Electrical plants, however, must supply the current directly as needed. Every increase or decrease in the number or candle power of the lamps burning must be instantaneously met by a corresponding change at the dynamos and steam plant. This state of affairs must continue until some of the many storage batteries now being exploited are shown to be sufficiently efficient, durable and cheap to justify their general adoption. Until then, those plants which do commercial lighting must necessarily, at times of greatest output, be forced to their utmost capacity, and at other times do little or nothing. Under such conditions economy of steam is out of the question. The *real* efficiency must be measured from the plant as a whole, and is a problem of considerable complication. To ascertain the actual cost per lamp hour, the items of fuel, salaries, oil and other supplies, lamps or carbons, interest, depreciation, repairs, losses due to poor service, interruptions, etc., must be given due weight. In the designing of a new station, it is of even greater importance to give each element of cost its proper consideration. No general rules can be laid down for guidance in studying a problem as complicated as this one. Some of the more important factors may, however, be mentioned.

Whatever the general design of the plant, whether arc or incandescent lighting, or power, whether high or low tension, large or small, whether fuel is high or cheap, space costly or not, the one condition to which all others are secondary, is complete *reliability* under severe and continuous service. The public has a right to demand, and does demand, that the lights be always ready, and maintained to their full candle power. An interruption means, not only a loss which cannot be regained, but an injury to the standing and record of the enterprise which months of steady running cannot counteract. Reliability can be secured by using only the best of machinery, as simple in construction as possible, cared for by good men. The plant should be divided into such units that in case of accident to any part of it, that part may be thrown out of service, and the work assumed by the remaining apparatus, without straining the machinery, or interrupting the output. This means a reserve sufficiently large to carry the work of any unit of the plant.

The particular electric system in use is the consideration of next importance. The cost of conductors, space required, closeness of regulation necessary, capacity and number of dynamos, all effect the steam plant. Low tension systems require costly conductors, and must be located close to the center of maximum lighting. Ground is here very valuable, and the most important requirement is to get the plant into the least number of cubic feet. High-duty engines occupy too much space, and water for condens-

ing is usually not available. On the other hand, high-tension systems are less affected by distance and should be located where land is cheap, and, if possible, where cars loaded with fuel can be switched alongside the boilers, and where an abundance of water may be had for condensers, or best of all, where water power is available.

The cost of the ground occupied, therefore, affects the arrangement of the plant and type of machinery.

The cost of fuel, as compared with its heat value, is of scarcely less importance than the system itself. If fuel is cheap, costly and complicated machinery to economize it is not justified. If high, it should be adopted as far as other conditions will permit.

The cost and quality of the water supply are important in selecting the type of boiler, heater, etc., and deciding the question of condensers.

The distribution of the load through the hours of the night is worthy of careful consideration. High fuel economy is attainable only under certain fixed and favorable conditions. Among these the most important is the point of cut-off in the engine at which its efficiency is a maximum. The best authorities place this at between $\frac{1}{5}$ and $\frac{1}{4}$ for single cylinder engines, working with initial pressures of from 80 to 100 pounds, above the atmosphere. Both earlier and later cut-offs, mean more fuel per horse power. In the latter case we exhaust the steam at too high a pressure, and in the former the cylinder condensation increases so rapidly as to nullify gains from higher expansion. It does not pay, therefore, to use large engines when the load is at times small. The units of power should be so selected as to enable the engines to be run close to the point of cut-off of maximum efficiency. As the load changes, engines may be started or shut down, so that at most only one small engine is worked at a disadvantage. Having selected the size of engine best adapted for the work, there are advantages in the way of simplifying the attendance, care, repairs and general arrangement, by reduplication of parts throughout the plant.

Other conditions, which, while of minor importance, must not be lost sight of, are : The nature of the plant, whether permanent or temporary ; the amount of capital available, which, however promising the returns, can not always be secured to carry out plans in the best manner ; and provision for growth. This latter is too frequently overlooked. No industry is capable of greater expansion by means of good service and reasonable charges. It often happens that after only short service the demand becomes such as to require extensive enlargements. If this necessitates the remodeling of the entire station, it can only be done at greatly increased expense, and sometimes with serious interruptions to the service.

All the large steam plants in this country are arranged on one of two general plans, which differ in essential characteristics. One school advocates the use of large slow-speed engines, belted to counter shafts, which run at increased speeds, and on which are placed friction-clutch pulleys and clutches, enabling any dynamo or engine to be thrown in or out of service at any time. To get the full benefit of this system the engines must be large and few in number. In practice two engines are generally used, belted to opposite ends of the counter shaft. The other school prefers smaller, independent engines, of the high-speed type, belted direct to the dynamos. Each plan has its warm advocates, and arguments are

not lacking on either side. Which of these plans to adopt is the question which confronts us at the outset. The answer in any given case involves a careful study of the points I have discussed, and presents a problem of no small magnitude.

Two important advantages are claimed for the system using large slow-speed engines. First, the long-stroke engine, with four independent valves, represents the highest known steam efficiency, and requires smaller boiler plant and less outlay for fuel. Second, the use of shafting and clutch pulleys admits of the greatest interchangeability. Any dynamo can be run from any engine, and a dynamo or engine can be thrown in or out of service without affecting the rest of the plant.

On the other hand, the advocates of direct connected engines claim, 1st, that no power is lost in driving shafting; 2d, that as stations are actually run under widely varying loads, the small engines can be operated at or near their best point of cut-off, and will, therefore, do the work at less fuel cost per lamp hour; 3d, that one or two dynamos to an engine offer all necessary interchangeability; 4th, that one small engine affords ample reserve; 5th, that electrical conditions demand close regulation of speed, from stroke to stroke, and under changing load and steam pressure, and that experience has shown that this is best secured by high-speed engines: 6th, that a short circuit in a dynamo would slow down a small engine, thus giving warning of danger, while a larger engine would pull it through, regardless of results; 7th, that the plant occupies the least space; and last, but by no means least, the first cost, including erection and foundations, is less than for low-speed engines with shafting, etc.

That there is wide difference of opinion among prominent engineers on this question is shown by the fact that there are now being erected stations costing hundreds of thousands of dollars on both principles. Let us examine the claims made in the light of the requirements already laid down.

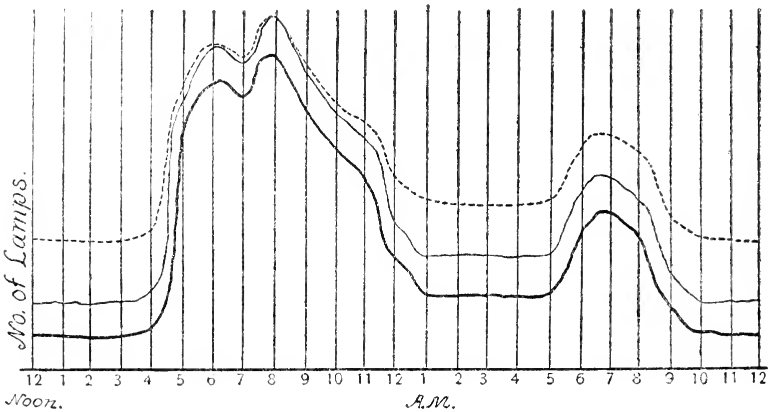
First, as to reliability. Both plans claim simplicity of construction, but in my opinion "honors are easy." Two engines are, of course, easier cared for than a dozen, but as each of the large engines is not only much heavier than one of the smaller ones, but is more complicated in its valve gear, and the plant is further encumbered by the shafting, with its necessary bearings, couplings and clutch pulleys, we see no difference in the two. The large countershaft is a source of weakness, however; an accident to it means a suspension of the whole plant. The service required of it is severe, and it is not always easy to preserve the alignment. When out of line it consumes great power, and is a source of constant worry and danger. An accident to one of the large engines means a serious loss of capacity, while it is insignificant if the engines are small. In the latter case a reserve engine means a much smaller investment of idle capital and space. It appears, therefore, that independent engines are preferable on the score of reliability.

Second, as to the electrical system. If the plant can be located where there is abundant space, it may be planned with a view to the highest efficiency. If other conditions permit, all the advantages of high expansion and condensing engines may be utilized. On the other hand, if ground is valuable the use of direct belted high-speed engines is necessary.

In those systems requiring close regulation of speed, they are also preferable, although slow-speed engines are being greatly improved in this respect by new designs, better workmanship, and the use of heavier fly-wheels.

Third, as to their fuel economy. It is here that the advocates of long stroke machinery make their strongest claims. I have been unable to secure exact and reliable data as to the water consumption of the two types of engines, per horse power per hour. From the best information I can get, however, I am inclined to place the water consumption of the low speed at about 20 per cent. less than the high speed under similar average working conditions. Where fuel is expensive, and where the other limiting conditions mentioned above do not prevent, the low-speed engine should therefore be adopted.

There are, however, two important points which must be considered in this connection. The useful power delivered to the dynamos is always less than that exerted by the engine, by the amount of the friction of the engine and power-transmitting devices. In direct connected engines this



loss is from 7 to 10 per cent. of the total, while with the shafting system it is usually from 20 to 25 per cent., and if the shaft is out of line, may be much more. It thus appears, therefore, that a large part of the superior economy of the low-speed engine is offset by the increased friction loss.

The economy is further affected by the amount and hours of loading. If the work done is large and constant, as is the case with plants operating contracts for city lighting, the low-speed engine has still a good balance in its favor on the score of fuel economy. If, however, the load is subject to wide fluctuations, as it is with commercial lighting—especially incandescent plants—the case may be different. The *real* efficiency can not be measured under the best conditions but for a whole day's run. The accompanying sketch may be taken as typical of the work of all incandescent plants doing commercial lighting. The lower curve represents the net output of the dynamos measured in lamps burning; the next line shows the additional work done in friction, which is constant for all loads. It will be noticed that a single large engine doing this work must, for three-

fourths of the time, cut off at points decidedly unfavorable to its economy. That is to say, that the steam required to operate the engine under these conditions, would, if used in an engine cutting off nearer its point of maximum efficiency, do a great deal more work. The upper line represents the work which the steam consumed is capable of doing, if properly used. You will, no doubt, be struck by the amount of steam used wastefully, as shown by the irregular space between the upper and lower curves.

By dividing the work among several smaller engines, which can be shut down and started up as required, but one engine, at most, works at a disadvantage. The friction loss is also less, and when each engine shuts down its proportional amount of friction ceases. It is evident, therefore, that independent engines have a decided advantage in net economy under variable loads.

I had intended to submit sketches of a plant of say 1,000 H. P., arranged in both ways, making a calculation of the efficiency of each, under variable loads. On investigation, however, I found that the ground had already been covered in an able paper by Mr. W. L. Church, read before the National Electric Light Association, at its meeting at Pittsburgh in February, 1888. Mr. Church presents data from two actual stations in which the ratio of fuel per lamp hour is as 70 to 126, in favor of independent engines.

Summing up, it appears that long-stroke engines are to be preferred where the load is approximately constant, provided sufficient space can be had, and provision is made for reserve. But for variable loads, and where space is valuable, as well for greater reliability and closer regulation, the use of high-speed engines appears to offer most advantages. The most prominent promotors of incandescent lighting in this country have adopted direct connected engines for their central stations.

A brief discussion of the integral parts of a steam plant for electrical service may be of interest.

The engine we have already considered at some length. The advantages of compound, triple expansion and condensing engines, are well known, and these principles may be applied with benefit to both low and high speeds types. It must not be forgotten, however, that their recognized fuel economy is secured by greater complication of parts. A higher degree of skill is, therefore, required to operate them, and the liability to accident and derangement is increased. The full benefit of these principles can only be obtained where the load is large and approximately constant. It is evident, therefore, that these high types of engines cannot always be used with benefit. The success of stations now being equipped with high-pressure boilers, and triple expansion condensing engines, will be watched with interest.

All sorts of boilers have been used, from the long cylinder, where fuel is cheap, or the water bad, to the water tubular. Each has its advantages. The horizontal tubular boiler is a quick steamer, occupies little room, is not high-priced, and is fairly efficient. Among these, my own preference is for the boiler with four-inch tubes, as it seems a happy mean between the flue boiler and the multi-tubular. The water-tube boiler is being widely adopted in electrical plants. Its advantages are: high efficiency; small space occupied; capacity for over-work; quick steaming, and safety.

The type of boiler to be selected is usually determined by the quality and price of fuel, the space available, and the scale-making properties of the feed-water—although it is claimed the latter has now been eliminated by the invention of purifiers guaranteed to keep boilers free from scale.

The design of furnace and grate is also determined by the fuel. The furnace is modified by the question of whether *capacity* or *fuel economy* is of more importance. Rocking grates and mechanical stokers have points of value, but cannot be used successfully with all fuels. The use of petroleum as a fuel is increasing, as was shown by the interest in the subject at the recent meeting of the National Electric Light Association at Chicago. Comparing Illinois coal, a pound of which evaporates six pounds of water, and which costs 8 cents per bushel in St. Louis, with petroleum having an evaporative efficiency of 16 to 1, the oil must be furnished at less than 2 cents per gallon to make the fuel cost of evaporating 1,000 pounds of water the same in both cases. When we consider the greatly reduced cost of handling petroleum, and the exactness with which it can be regulated and controlled, and the fact that it is smokeless, it seems destined to wide adoption.

A handsome brick stack seems to me a desirable feature of any plant. Its solidity, strength, beauty, efficiency and absence of repair bills are worthy of consideration.

I have found the following formula useful in stack calculations:

$$a = \frac{100\, w}{d \sqrt{2\, g\, H \frac{D-d}{D}}}$$

in which

H = height of stack in feet.

a = area of stack in square feet.

w = pounds fuel to be burned per second.

D = weight of one cubic foot of air.

d = weight of one cubic foot of chimney gases.

g = 32.2, the acceleration due to gravity.

If the outside temperature be 100 degrees F. and the inside 450 degrees F., the formula becomes

$$a = \frac{460\, w}{\sqrt{H}}, \text{ or } H = \frac{211{,}600\, w^2}{a^2}$$

In non-condensing plants the exhaust steam should always be used for heating the feed water. The quality of the latter is the determining factor in selecting a heater. There should be ample settling capacity, and the water should be outside of the tubes, which should be of brass or copper. There should always be a relief valve on the feed pipe near the heater, so that overpressure can not injure the tubes. If the water is very bad, it should be further purified by live steam. Heaters and purifiers should be so arranged that they can be frequently blown off, and also examined and cleaned without interrupting the service of any part of the plant.

For boiler feeding, I prefer a direct acting, single pump, brass fitted. It should pump cold water through the closed heater, and if the water is gritty, should have outside packed plungers. The boiler-feeding apparatus

is perhaps the most sensitive part of the plant. Instead, however, of providing two pumps and heaters, a first-class injector can be used. It is not only perfectly reliable, but ties up very little capital, occupies little space, and can, when called upon, take the place of either the pump or heater, or both.

The pipe system connecting boilers, engines, heaters, pumps, etc., is worthy of careful study. The points to be borne in mind are: Abundance of area, as direct lines and as few bends as possible: suitable provision for expansion and contraction, and drains. By means of return traps all condensation in the live steam pipes can be returned to the boiler. These pipes should be well protected by non-conducting material.

Belting is also of great importance. Its slip must be a minimum. It must be well made and of good material, to be durable and reliable at speeds of a mile a minute or more. I have here a sample of a leather link belt which is proving popular. It is so heavy and pliable that its arc of contact on the pulley is much greater than with ordinary belting. It can, therefore, be run very slack, thus avoiding the great strain on engine and dynamo journals which is usually required to prevent belt slip. It also prevents air cushion. The driving and driven pulleys can be brought very close together. Transmission of power by ropes instead of belts is now being tried, and has some advantages. They are very cheap and easily replaced. The ropes run in V-shaped grooves, which render slip impossible. Sometimes a single rope is used, which encircles the pulleys a number of times, and is kept tight by passing over an idler, in the same manner as street railway cables. This arrangement is open to the serious objection that an accident to the rope means a shut-down. This could be obviated by dividing the rope into a number of parts, each independent of the other. The number should be sufficiently large that in case of accident to one, the other ropes could carry the load until the engine could be shut down. As there is some elasticity in the rope, it is not certain that tightening devices would be required, but if they were they do not seem to be impracticable.

It will be seen that this discussion applies to the driving of dynamos of all kinds, without reference to the work being done. In arc lighting, the load is frequently nearly constant, but in incandescent plants, and for street railway work, the power required at different hours of the day and night varies greatly. The amount, and hours of loading seem, therefore, to be the factors upon which the selection and arrangement of the steam plant are most largely dependent.

HOW SHALL WE WARM, VENTILATE AND CLOSET OUR SCHOOL BUILDINGS?

By N. B. Wood, Member of the Civil Engineers Club of Cleveland.

Read June 11, 1889.

In former times, when the training of the youth was a matter of individual enterprise, or carried on under the influence of a more congenial climate, or when the construction of houses was unconsciously more in accordance with sanitary principles, being loose jointed at the expense of

comfort, and thus preventing suffocation, little attention was paid to the matter of ventilation, and since general comfort in the matter of warming was not known to any great extent, no complaint was made if a scholar was too warm on one side and too cold on the other. Only too happy was he if he were so situated that he could occasionally change sides; or if he were so unfortunate as to be out of range of the heat, he considered himself very fortunate if the teacher would allow him to occasionally take a front seat, book in hand, and toast his almost frozen toes for a brief interval of time.

If a child showed any signs of impaired health he was not considered fit for education, and was put to some practical labor or business, when he not unfrequently outstripped his more fortunate comrades, both physically and mentally.

In these days, when every one must be educated because every other fellow is, when our schools are crowded to their utmost capacity, when the size of our school buildings and the perfection of the workmanship render natural ventilation impossible, the need of ventilation is better understood. We find as much attention paid to it and the general comfort of the occupants of such buildings as is bestowed upon their external appearance.

The great difficulty which attends coming to correct conclusions about the problems involved in heating and ventilating is the fact that the actual movements of the air are invisible and imperceptible. In consequence of this almost any method of procedure may, by specious reasoning, be made theoretically to fill the exact requirements. But if we could see what was really transpiring we should find, very often, exactly the opposite did occur. Experimentors have made the motions of the air visible by means of various vapors or finely divided substances, which are visible and float; the best of which is chloride of ammonium, formed by injecting hydrochloric acid with an atomizer into the atmosphere previously charged in like manner with ammonia. The resulting milky atmosphere can be very readily observed and its movements noted. But t is very doubtful whether these experiments have been carried out under the same conditions with which practical warming and ventilating have to contend.

It has been assumed that if a certain effect is produced by a certain cause the same effect will always follow when the same cause is brought into action. This is obviously absurd since the other element, which determines the nature of the action, has been left out, namely, the conditions. In fact, on this particular subject too much has been assumed and too little has been demonstrated. It may be assumed, however, that any assumption contrary to any of the following facts cannot be demonstrated to be true: That carbonic acid is heavier than air (1.5). That the vapor of water is lighter than air (.625). That gases and vapors enjoy a peculiar property called diffusion, which enables or forces them to mix uniformly, even against the force of gravity. That the specific gravity of such mixtures is equal to the mean of all the component parts, and, that when warmed all such mixtures are lighter than when cold. That when the condition of the air is normal it contains about four or sometimes five parts, by measure or volume, in 10,000 of carbonic acid, and if the quantity

is much increased the result is very disastrous to health. The various methods of heating and ventilating may be divided into two distinct classes:

First: That which is forced by mechanical devices.

Second: That which is effected by gravity, or by the difference between the weight of a column of warm and cold air.

The first, no doubt, is practical and preferable in some cases, as, for instance, in mines; but for the purpose under discussion cannot be thought of, because its first cost is too great. It is too liable to get out of order. The expense of running it, both as to fuel and labor, is excessive.

Let us then consider some of the gravity methods.

First: That in which no provision is made for ventilation except by opening the windows at the top for foul air to escape and at the bottom for the admission of fresh air. A steam radiator is placed in front of the window. which admits the fresh air, and is expected to warm it as it enters to take the place of that making its exit from the windows above.

This method cannot be too strongly condemned. It amounts practically to no ventilation at all at those times when ventilation is most needed (*cold, stormy weather*), and yet is the one used more than any other. Our Central High School building is warmed but not ventilated in this manner, and if the good people who made such a vigorous fight against the Smead dry closets had used as much energy in ridding the city of such a blot on its educational system they would have done the city and humanity a benefit instead of an injury.*

Second: That in which fresh, warm air is allowed to enter the room (when the conditions will permit), and the cold and contaminated air is supposed to make its exit through the imperfect joints. It is very evident that such a method offers a premium on poor workmanship, since good joints prevent both warming and ventilation, and besides this the openings are as likely to be left at the top of the room, where great loss of heat would occur by leakage of warm, fresh air, and less likely to occur at the bottom or below the windows, where the scholars sit in a cold stratum of air, which must be foul for the same reason that it is cold, because it cannot be changed.

Third: That in which the warming apparatus is in the room, as in first. and the ventilation carried on by means of openings at or near the floor. which, supposing the foul air to be heavier than the other in the room. takes away all the objectionable contents by being connected with a ventilating shaft where a current is kept up by a small fire or coil of steam pipes. The fire is preferable because in warmer weather no ventilation could be kept up unless the main boiler was fired, which would be expensive. This method would be very good if the supply of air was adequate and the theory correct with regard to density of foul air. But it is evident that, when the room has become too warm and the steam has been shut off, the air in the upper part of the room will rapidly become impure, while a stratum of cold air will occupy the floor with a current running across it from the windows to the ventilating stack. Another variation of this method is to place the opening to the ventilating stack (or flues) at the top of the room, the heating being done in the same way, which I

*The writer has since learned that this is not exactly the method used, but practically the same.

should think would be more objectionable than the last mode, since if it were large enough it would take all the heat out of the room, including the products of respiration, and keep the room cold, or if too small would not ventilate.

Fourth: That in which fresh, warm air is supplied to the room, and means provided for the cold and foul air to pass out at the bottom of the room. This method affords good ventilation when everything is favorable, but if the room happens to become too warm and the registers are closed, no opportunity is afforded for ventilation either by diffusion or otherwise. The room would fill from the top downward with impure air, and when the registers were again opened the room would have to be filled in the same manner with warmer and fresher air before the heads of the occupants would get into a medium fit to breathe. Possibly under the influence of adverse winds we might have the current in the wrong direction, with plenty of fresh air and no heat, or with air which had been used in another room.

The number of methods might be continued almost *ad infinitum*, but as the object of this paper is to bring before your notice a system which, though open to some criticism, is the nearest perfect of anything which I have been fortunate enough to inspect, we will proceed immediately to its consideration. What is known to us as the Smead system of warming ventilation and dry closets is a combination of what heretofore has been two distinct branches of building construction. Though the dry closet is by no means inseparable from the very excellent system of warming and ventilating, it seems so naturally to be a part of it and to give such remarkable results that it seems a great pity to separate them. The means used by this method of warming and ventilating are a combination of some of those already mentioned.

The warm air being admitted to the room through openings, which cannot be closed, near the floor, and openings nearly all around the room in the base being provided for its exit when spent.

The points of excellence are a peculiarly constructed furnace of extremely large heating capacity, connected with the warm-air ducts and the fresh-air chamber, which is above ground, that when a valve is turned to cut off heat, it at the same time turns on cold air, thus always insuring a supply of fresh air. The exit ducts are arranged about the bottom of the room, near the floor and under the windows, in such a manner that the air will pass under the whole floor on its way to the ventilation stack, thus keeping the floor warm and dry. Now remember that this is not a hot air but warm air system, not intensity but quantity, the temperature of the warm air being about 110 degrees and the temperature of the room being kept at about 70 degrees, with a variation of not more than 3 or 4 degrees between the top and bottom of the room. This smallness of difference of itself indicates how perfect must be the ventilation. It would seem that the expenditure of fuel must be very great where such a large quantity of air is passing out at the temperature of about 70 degrees, but carefully kept accounts between buildings warmed by steam and those warmed by the Smead furnace showed decided economy in favor of the latter. In addition to these few but important elements of superiority we may place first cost, cost of repairs, absolute freedom from

danger by explosion and less liability to general accidents and consequent interruptions from such accidents as bursting of pipes from freezing, from corrosion, faulty connections, etc., etc., besides not requiring so much skill in management.

The only fault which I am able to point out is one which is common to nearly all systems I have mentioned before, and that is its arrangement of air ducts, which, as Mr. Smead says, depends for its action on the products of respiration being heavier than air in its normal condition. The fact being that when first expelled from the lungs at a temperature nearly 100 degrees, and charged excessively with vapor of water, it would be nearly as light as the warm air being introduced at nearly or about 110 degrees, but this is undoubtedly so largely diluted by the constant stream of warm air as to be practically innoxious; but suppose the room becomes too warm and the warm air is shut off? By the automatic arrangement cold air immediately begins to pour in, and fills the lower part of the room, buoying up the lighter impure air until the room becomes cool enough to turn on the warm air again. In cold weather this will occur soon, and cause no inconvenience, but when warmer weather comes nothing can be done but to open the windows. My opinion is that smaller registers should be put in near the top of the room operated automatically, so arranged that they would open when the warm air is shut off. Then, in my opinion, we should have a system of heating and ventilation which would be independent of windows or doors both winter and summer.

For closets we have only three systems which are in use to any extent. The outside closet, with vault, which must be ruled out without consideration from any civilized city use. Outside closets, connected with sewers, are little, if any, better, and if we accept the germ theory of disease propagation, and sewer-gas conveyance of such germs, even worse. I need not describe or discuss the inside water closet. You are all familiar with them. If they, or any of them, are perfect they are expensive and liable to get out of order, which means expensive to maintain, and I have yet to see one which was not disgusting either in itself or in its use. Of course I don't entirely proscribe their use. In fact, I think that, like a great many other city contrivances (stone pavements, for instance), they are a necessary evil; but I do think that they are not to be thought of for school purposes when we have something so far superior to them that its adoption is becoming almost universal. I have reference to the Smead dry closet. In this we have a system that is as perfect as human ingenuity can well devise. The foul spent air from the rooms above is concentrated into one chamber, which is connected with the ventilating stack, where a small fire insures a perfect draught, by a horizontal shaft about three feet square. On this are placed the seats in a long row, the deposits being received on a porous brick platform, over and under which a continuous current of dry air is passing on its way to the ventilating shaft. The effect is marvelous. Instead of being a room which is visited only in cases of urgent necessity and avoided on all other occasions, it becomes a play room and lunch room for inclement weather, and as the recent investigations at our Central High School showed by the analysis made of the air by the Board of Health, the closet room had the purest air in the building with the exception of

the principal's office; the amount of Co_2 being a little over five to ten thousand in the closet, and four or a little more in his room, while it amounted to more than twice that in the school rooms. No wonder the scholars were subject to the headache. But, say the people who were frightened by the newspapers, the system is all right in the schools, but you are contaminating the air of the neighborhood by the horrid and unheard-of method of drying up the excreta of over a thousand pupils under our very noses, and scattering the germs of disease broadcast through the populous part of the city.

The people of the vicinity assumed that the mephitic vapors which were forced up the stack fell down outside and enveloped a helpless community in their foul embrace, creating any amount of sickness and death. Let us see how this works, if we reason on fact and not on assumption. What would be given off in the process of drying which would be likely to contaminate the air, and what would become of it? What chance would there be of germs of disease escaping and becoming active agents?

The result of drying would be principally water, 75 per cent. of solid excreta being thus composed, a little (very little) carbonic acid, a very small quantity of ammonia and some of its compounds, and a quantity of hydrogen sulphide too small to weigh, all lighter than air, except the minute quantities of Co_2 and hydrogen sulphide. It does not require a great deal of sagacity to answer the last portion of the question. If there is anything positively poisonous in the substances and quantities named, I fail to know of it, and if there was, being lighter than air and liberated fifty or more feet from the ground, it would never return to earth until by diffusion it had become so diluted as to be normal air. As to germs, they are an unknown and purely theoretical quantity, but the various *bacilli* are known to be very much like fish out of water when in dry air, and soon perish; but whether or not the germs, if any, are disposed of in this manner would be doubtful. We cannot say much about a thing of which we have no knowledge, but we can safely say that they would follow along with the gaseous discharge from the stack until, if not destroyed by dry air, they would reach an altitude where a lack of genial temperature would end their existence. We must not forget, too, that every house which has a water closet has a pipe which discharges whatever sewer gas and other emanations are bred within, and known to be dangerous if found within the house. How is it they are not dangerous?

I have now described to you a system which above all others that I know of meets with my approval; clean and wholesome, with no expensive fittings and nothing to get out of repair, a complete solution of the problem of how to avoid a good part of sewage contamination; a method where an undesirable object can be disposed of easily by fire, for it is capable of being burned just as it lies, or profitably applied to the soil as a fertilizer. I say by all means let us have the Smead system, improved as I have suggested, in all the school buildings where the prejudice of the people will permit.

DISCUSSION.

Mr. A. H. Porter: Is this extra register for an entrance or an exit of the air?

Mr. N. B Wood: It is for an exit of the foul air. The warm air duct is closed, and the cold air comes into the room. All the warm and foul air, which is

light, will lie upon the top of it. The air will all become foul unless a means of exit is provided.

Mr. A. H. PORTER: Would it not be better to place the cold air register at the top?

Mr. N. B. WOOD: That would be like pouring a bucket of water in—the cold air would sink to the bottom and the result would be the same.

Mr. B. F. MORSE: My recollection of the ventilation of the High School Building differs a little from Mr. Wood's explanation. As I recollect it, the cold air was taken in at the base of the lower window sash, and was heated by passing through a steam radiator. It then passed through the room and out through the ventilators in the floor, and directly into the stacks. There are six registers in the floor of each school room, besides a large register 24 in. by 30 in. set just above the floor, opening directly into the ventilating stacks.

Mr. N. B. WOOD: I did not examine the place closely, but was under the impression that it was as I described.

Dr. ASHMUN (Health Officer): The ventilators for the escape of foul air have all been bricked up. The ventilators in the floor are filled with papers and dust. There is no air passing through them.

Mr. B. F. MORSE: In each of these rooms there were six registers in the floor, besides the large 24-in. by 30-in. register set in the stack to conduct the foul air into the ventilating stacks. When they put this Smead system in they conducted the foul air from the Smead closet into two of the stacks, and when the wind was blowing strong from some directions the foul air from the Smead closets passed out into the rooms, as I have been credibly informed. I will not say that the Smead system is not good in some respects; but I think the way it was put into the High School building was an outrage. They bricked up the registers so that there was no ventilation at all in the rooms.

Mr. N. B. WOOD: But was there not a continuous current of air drawn out of the room by the dry closet ventilators?

Mr. MORSE: Not when the fires were down and the wind blowing in the wrong direction. A short time ago I was in a small place where they had a new building with the Smead system in it I went in and found that they were running the two boilers for heating that day. I went into a room where the Smead closets were in operation and tested the current by lighting matches. In every case the smoke and blaze of the matches rose into the room. There was no current to draw it down. I made up my mind that the closets required as close watching to make them work as a steam engine does while running.

President WARNER: We would like to hear the opinions of our architects. Perhaps Mr. Richardson will tell us what he thinks of the Smead system.

Mr. J. N. RICHARDSON: I know nothing of the Smead system except what I have heard from Mr. Wood. So far as the heating and ventilation of buildings is concerned, that system was used in Pittsburgh some years ago. They used coils of pipe for heating and the furnace chimney as a ventilating stack. It worked very well in the Pittsburgh courthouse. It was described in a book on ventilation by Leeds some time in 1868 or 1869. Mr Leeds claimed that the carbonic acid gas was heavier than good air, and placed registers in the lower part of the room. There were registers in the upper part of the room to carry off the products from the gas jets. It was found that ventilation by the chimney stack was not always a sure thing; the quantity of air removed and supplied could not always be counted on. Of late they have been applying to buildings in New York, Chicago and other places the fan system. They seem to prefer the plenum system, as they call it. That is, forcing the air in; the pressure of the air will then always be outwards and prevent inward draught. They have flues all round the room so that the foul air may go out. They have a heating apparatus with steam or warm water, and flues go from this connected with air

chambers. By adjusting a valve, you can bring the air in at any temperature you choose. Most of the churches in New York are ventilated in that way. The fan can be made to run at any speed, giving any required amount of fresh air. Of course, that would be too expensive to put into a school building, so probably the next best plan is to exhaust the air by means of the furnace chimney. Our plumbing arrangements are now first class as far as water closets are concerned, and I think they can be put in so as to be perfectly pure and healthy. The science of sanitary engineering has improved a great deal within the past five or six years. In some buildings each water closet is connected with a flue for itself; in that flue there is a small gas jet burning. I have seen plumbing fixtures in a business building in New York where you could apply a match to any fixture, and the flame would invariably go down. The Masonic Temple has that arrangement in the water closet departments.

Mr. WOOD: The objection to that is that though you may have an excellent system you have the expense of the closet added to the expense of the Smead system, and have not then as good a thing as the Smead system. In the Smead system the closeting for a whole building will only cost about $150. If our Board of Education should put in an arrangement for blowing in air, and this improved water closet system, there would be a howl about the expense.

I have here a little table with regard to the proceedings of the Board of Health for the State of Ohio. It amounts to this, that in a building having some 400 scholars, the changes of the air in the room were every six minutes. The highest amount of carbonic acid was 55 and the lowest 37. The average was 44.3. The temperature of the room was kept at 75. The average cubic feet per hour was 79,000. The average changes in this room were 1,700 cubic feet per capita per hour, which, I think, would be a pretty liberal supply.

President WARNER: On Wilson Avenue we have the largest sewer in the city, and it has been practically closed on account of the Smead system.

Mr. WOOD: I would like to hear the opinions of some of our friends here with regard to the likelihood of germs being given off by the Smead system. What is the comparative danger between the two systems?

Dr. G. C. ASHMUN: The inter-joist spaces utilized by the Ruttan-Smead system for conveying foul air are about the best places for the collection of dust and germs, and perhaps for the distribution of them. The danger of spreading scarlet fever is greatest in its latter stages, on account of the "peeling," or desquamation of the skin. These particles, drawn into the inter-joist spaces, may be disseminated by this system. As a means of removal of foul air, it must be remembered that where "stringers" or "beams" interfere, the full inter-joist space cannot be secured, but only the space afforded by cutting away a portion of the beam between the joists. In time, where so much dust is conveyed in the air, the rough lumber of joists and beams becomes covered and "woolly" from the particles deposited, thus interfering with free circulation of air.

Another objection arises from the fact that it is possible to reverse the draught in those buildings where there is not considerable heat in the stack. Where the heat in the stack is nearly or quite withdrawn, there is grave danger of the draught being reversed. Two weeks ago, in the presence of a number of physicians, it was demonstrated that air was carried from one room to another by this system, even when there was a good fire in the stack. I do not think there is much danger of distributing disease germs from the stack into the air outside the building. I doubt if any of the germs carried out in that way produce any injurious effects, but if air can be carried from one room to another injury may come from it.

To my mind, one serious defect is the fact that the dried excrement remains in the building. At the Waring street school all the excrement deposited since the school opened, Feb. 1st, 1888, remains in the basement of the building. It might

have been removed, but it has not been considered necessary. If the draught is uncertain, the organic particles may come into the building, for they are dependent upon the constancy of the draught to keep them out. It is supposed that the movement of air at the top of the stack will be sufficient, but as we have demonstrated that it has reverses, the presence of the large mass of excrement in the basement, and the other factor of interference of the passage of air through the inter-joist spaces after dust collects, demand serious consideration in estimating this system in comparison with others. It seems to me that the statement made in Billings' work is likely to be true, *i. e.*, that this system of ventilation works best in the early years of its use.

A MEMBER: Ten years ago we had occasion to examine the air in some rooms in Buffalo. In one room we found that about 5 ft. from the floor the ammonia was the strongest, at the floor was next, 8 ft. above the floor was the next, and at the ceiling there was least. That was the old-fashioned school room, ventilated by opening a window.

MR. J. A BIDWELL: The great difficulty in this High School building is to regulate the draught. That might be remedied in several ways. It appears to me that the most practical one is to build a tall chimney. Your chimney must be larger than all the openings into it, and it must be high enough to produce the current required. When I built a factory here I was obliged to build a chimney 125 ft. high and 6 ft. area. When you connect this Smead system, which is dependent purely on your current, with a chimney of sufficient height, your difficulty will be removed.

MR. RICHARDSON: I was under the impression that taking the air inside, say, at 70 deg. and the outside air at 40 deg., that the air at 40 deg., being heavier, would force its way down. I would reason that the chimney in the Smead system would sometimes draw down instead of up, unless kept heated, depending on the difference of temperature between the air in the room and that in the chimney.

(Mr. Bidwell's reply to Mr. Richardson is omitted here because the substance of it will be incorporated in a paper on ventilation.)

MR. WOOD: With regard to cleaning up these places, it is a question in my mind whether it is necessary. The matter is perfectly dry and evidently inert. But if it is necessary to clean it out it can be burned just as well as not. It can be taken out and carried away. In regard to back currents, Mr. Smead invented a valve to prevent back currents. He has a valve of that kind, but it was not put on because it was not necessary.

MR. MORSE: I cannot reconcile myself to the idea of connecting the foul air of the closets with the ventilation of the room. In parts of the city where there is no water sewerage, the Smead closets might be all right, but they should not be connected with the ventilation of the school rooms.

MR. LEOPOLD DAUTEL: I was originally in favor of the Smead system, but Dr. Ashmun's remarks have changed my opinion of it.

EDWARD SOUTHWICK PHILBRICK—A MEMOIR.

BY ALBERT H. HOWLAND, DESMOND FITZGERALD AND WALTER SHEPARD,
COMMITTEE OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read April 17, 1889.]

Edward Southwick Philbrick, son of Samuel and Eliza (Southwick), was born Nov. 20, 1827, and died Feb. 13, 1889. He was descended from Quaker ancestry that had been native to the shores of Massachusetts Bay from near the date of the settlement of Boston. He was born in Boston,

but except during early infancy his home was always in the adjacent town of Brookline. His father was a merchant in Boston, a director in several corporations, and for thirty years treasurer of the Massachusetts Anti-Slavery Society.

In 1843, after fitting for college at the Brookline High School, he entered the sophomore class at Harvard College. Paternal consent to this step, however, was conditional upon his living at home, walking the three miles each way to and from college daily, and spending no time on the study of Greek. These requirements were strictly complied with, but the restriction as to Greek prevented his receiving the customary degree on the completion of his course: at a later date, however, in recognition of his merits in other directions, the degree was conferred as of the class of 1846, to which he belonged. In the list of its members are the names of Senator George F. Hoar, Dr. Calvin Ellis, Dr. Charles D. Homans and Professors Francis J. Child, George M. Lane and Charles E. Norton.

In the summer of 1847, after spending a few months in the office of the late Samuel M. Felton, he began field work on the Rutland & Burlington Railroad, in Vermont, holding the position of assistant engineer on location and construction. Upon this work he was engaged some three years. Then going to Canandaigua, N. Y., he was employed in the construction of some branches of the Erie Railway. He held here the position of resident engineer of location and construction, and this work occupied another three years till near the end of 1853.

The decade that included these six years was marked by striking advances in the application of iron to bridge work. The great Conway and Britannia tubular bridges were built; the Victoria tubular bridge over the St. Lawrence at Montreal was begun; suspension bridges were built over the Ohio at Wheeling and the Niagara at Lewiston; and the great railroad suspension bridge at Niagara Falls was finished. Several of these structures were near the territory within which Mr. Philbrick was engaged in railroad building, and the subject of iron bridge construction so strongly engaged his attention that he soon took an opportunity to extend his knowledge of such structures as well as of public works in general.

A few months after he had finished work in western New York he sailed for Europe, and remained abroad a year and a half. Several months were spent at Paris in professional studies. Then, much of the time with knapsack on his back, he traveled through Great Britain, France, Belgium, Austria, Italy and Turkey. Passing beyond Europe he extended his travels to Egypt and Syria, spending in these countries the last six months of his stay abroad. Mr. Philbrick was a close observer, and being furthermore the possessor of a retentive memory, he gathered during these travels a store of information that was a frequent source of surprise to those with whom he conversed, minute details even not escaping him, especially such as had a professional bearing.

In the summer of 1855 he returned home and soon afterwards entered the employ of the Boston & Worcester Railroad as Assistant Superintendent and Engineer. For five or six years he was engaged in improving the location of the road and rebuilding some of its structures. A bridge that he designed and built during this period, namely, the

"Arsenal Bridge," in Brighton, should be mentioned in this connection, not on account of its size (for it is merely a plate girder of eighty-seven feet span in the clear) but as an instance of his early preference for riveted work, and as evidence of the soundness of his judgment in selecting at that day a type of structure for spans approaching even one hundred feet, that after a quarter of a century's experience has come to be pretty generally approved as the most suitable. This was built in 1860. In the early part of the next year Mr. Philbrick again spent several months in Europe.

Near the beginning of 1862, after Port Royal had been captured by the Union forces, and had become the refuge of the negroes of the neighboring country, true to his inherited anti-slavery principles and his own convictions, Mr. Philbrick undertook the organization of labor on a dozen or more abandoned plantations in that and the neighboring islands, including the education and training of the freedmen as citizens. Many volunteers from this vicinity accompanied and assisted him in the work, which was carried on for two years under the direction of the United States Treasury Department on government account. Subsequently the government sold the plantations for taxes, and the work was continued by a corporation formed for that purpose, which was successful commercially as well as in respect to its main purpose.

After the war closed Mr. Philbrick was employed upon some town improvements in Brookline and connected with some manufacturing enterprises. In 1869 he was appointed by the Governor of Massachusetts Inspecting Engineer of the Boston, Hartford & Erie Railroad, to which the State had made a loan of $3,000,000.

About this time the Boston & Albany Railroad was formed by the consolidation of the Boston & Worcester and the Western railroads. The traffic of the road increased to such an extent that the work of rebuilding its bridges in iron was decided upon and Mr. Philbrick was appointed Consulting Engineer and had charge of it. A large number of bridges were built, mostly between Worcester and Albany. The type he adopted was the riveted lattice, or for small spans the plate girder. The most notable among these bridges was that over the Connecticut at Springfield, and it occasioned a good deal of controversy as to the comparative merits of riveted and pin-connected trusses. Without entering into the details of the question (for the controversy is by no means ended) it seems proper to say that Mr. Philbrick's judgment is supported by the practice of some of the largest and best managed roads and that even pin-connected bridges in recent years have been made to conform in some features to the riveted type. Mr. Philbrick's preference for riveted connections did not extend to very large spans. Other works on the Boston & Albany Railroad constructed under his charge were the large Union Station at Worcester, and the grain elevators in Boston, that at East Boston being notable on account of the difficulties encountered in securing good foundations.

Near the close of 1868 the State of Massachusetts contracted for the completion of Hoosac Tunnel. The Troy and Greenfield Railroad Company had previously received State aid to the amount of several million dollars to build the tunnel and connecting railroad, but after twenty

years' efforts much the larger part of the tunnel remained unfinished and the State had come into possession. A year or two after the contract was made Mr. Philbrick was consulted upon some questions that arose as to alignment and quantities, and was soon afterwards appointed Consulting Engineer to the Governor and Council for this work, and held that position till the tunnel was opened. The amount of this contract was over $4,500,000. The accuracy with which the headings met was remarkable; at two miles from the east portal, where the heading from the central shaft was met, the deviation was only $\frac{5}{16}$ of an inch in line and $1\frac{1}{4}$ inches in level. Besides the tunnel proper there was a large amount of work in improving the line and building iron bridges on the connecting road, of which Mr. Philbrick was engineer.

The improvement of the flats at South Boston was also carried out under Mr. Philbrick's charge, and is a work of considerable local importance. The State contracted for building the sea walls and filling a portion of the flats in the latter part of 1873. A large area adjacent was owned by the Boston & Albany Railroad, and a contract was made for filling this at the same time. Mr. Philbrick had charge of this also. The territory thus made available now forms the terminal grounds of the New York & New England Railroad, provided with extensive freight sheds, grain elevator and wharves and docks for ocean steamers, distant only about a half mile from the post-office. These sea walls are notable for their substantial construction, and the Harbor Commissioners say, in one of their reports, that "no work, to their knowledge, has been undertaken in any harbor of our country superior in its design or workmanship to the plan and execution of the heavy sea wall, so far as it has progressed."

When the growth of the town of Brookline necessitated a public water supply the construction of the works was intrusted to Mr. Philbrick. The supply is taken from a filtering gallery near Charles River at a point a few miles from the town. These works were constructed during 1874–5 at a cost of a half million of dollars.

As a sanitary engineer, Mr. Philbrick had a wide reputation and was esteemed an eminent authority. The building, ownership and care of nearly a score of houses gave him opportunity for long continued experiment and a practical knowledge of the actual conditions to be met. The results of his experience in this branch of engineering were given to the public in a book on "American Sanitary Engineering," in pamphlets on "Defects in House Drainage and Their Remedies," and on "Disposal of Sewage in Suburban Residences," and in contributions to periodicals and discussions at society meetings. The publications form an interesting and important part of the sanitary branch of engineering literature. They have been extensively used in the practice of engineers and are often referred to as standard works on the subject.

Included in his professional practice were consultations as to the foundations of Trinity Church and the new public library building in Boston; service on commissions to award damages for diversion of water by the city of Worcester from Blackstone Valley, and by the city of Cambridge from Stony Brook, and to investigate the causes and management of the Great Fire in Boston; reports on sewerage in several

neighboring towns; building of highway and railway bridges over the Merrimac at Haverhill, and others of less note. New England is the field where most of his professional work has been done. Domestic ties and the care of a large property tended to prevent him from seeking other fields.

His membership in our Society dates from June 8, 1874, and in the American Society of Civil Engineers from May 6, 1876. The transactions of the latter contain several or his papers and discussions, among which is a paper on the South Boston Flats improvements.

Marked characteristics of Mr. Philbrick were a directness, simplicity and candor that won the confidence of those with whom he dealt. These qualities with his practical knowledge and varied experience caused his services to be sought for where the construction of expensive works demanded unquestioned fidelity and ability. With contractors he was sometimes considered rather strict, but he was fair-minded and considerate and ready to yield if he found himself in error. He was a man of varied interests: the newest book and the latest achievement of science received his attention.

Mr. Philbrick was free from all ostentation, and while professional duties and the care of his property and of trust funds engrossed much of his time, there were many enterprises benevolent in nature or aiming to promote the general welfare which received his active and devoted support. Well known among these is the Massachusetts Institute of Technology, of whose corporation he had for many years been an active member. In benevolent efforts his aim was to avert as well as to relieve misfortune and suffering.

As a citizen he was public-spirited, independent in politics, and deeply interested in whatever tends to promote good and honest government, often devoting time and money to this end though seeking for himself no conspicuous part.

In religious belief he was a Unitarian and served as treasurer of the First Unitarian Church in Brookline for many years.

On the 16th of September, 1857, he married Miss Helen M., daughter of the late Alfred Winsor, of Brookline, who, with his mother, now 96 years of age, are the survivors of his household.

The works of the engineer often receive but little of the popular appreciation that their merits deserve. They may be located in remote and unfrequented places, or buried where the light of day never reaches them ; often they are so unobtrusive that they seem to be almost a part of nature's own handiwork. Hence there is a peculiar satisfaction, when an occasion like this makes it fitting to recount them, in considering what a monument it is that he leaves behind him in the highways that bring to the people the products of a continent, the structures over which millions pass in safety, the warehouses where the food of the nations is stored, the grounds where the products of the world are distributed, the appliances that secure health to our homes. Such works bear witness to his skilful designing, fidelity in execution, patient toil in overcoming obstacles that seem almost insurmountable, foresight in providing for emergencies, correctness in reasoning, and an integrity that will not deviate from an honest course to secure in a day the profits

of a life-time. Such qualities will be freely ascribed to Mr. Philbrick; and the warm personal esteem of those who knew him well will ever cause them to hold him in grateful remembrance.

A SYSTEM OF MARKING PATTERNS. TRIED IN THE SHOP—WITH SOME REMARKS UPON ECONOMY AS VIEWED IN THE PATTERN.

By A. J. Frith, Member of the Engineers' Club of St. Louis.

[Read April 17, 1889.]

The following system of marking has been found so useful, that while it may not be especially novel, it is believed that it will be of interest to many. We are all aware of the great confusion that arises in the care of patterns, the difficulty of keeping the small parts of various machines to themselves, the perplexity in gathering every essential core box, etc., when old patterns are to be used, and the dependence on the special knowledge of one man when any particular casting is desired.

The desirable points in a system of marking patterns, to lessen this annoyance, were considered to be:

1. That there should be as little clerical labor as possible.
2. That a special familiarity with the machine should not be requisite when a casting is desired.
3. That one could feel assured when patterns go to or are returned from the foundry, that no loose pieces nor core boxes are missing, and do this without consulting unhandy records.
4. When patterns or parts of patterns become mixed together, which seems unavoidable, that any piece, no matter how insignificant, can be at once distinguished and sorted out by any careful employé.

To insure complete control over our patterns, it is first necessary that they should be marked and a list taken. This system was begun in the draughting room, where the drawing of each casting was given and marked with a consecutive number—all parts of one machine having a characteristic symbol.

Then in a small book these were recorded as follows:

THIRTEEN-INCH SLOTTER. SYMBOL S.

Consecutive number.	Sketch.	Name.	No of pattern.	No. of loose pieces.	No. of core boxes.
1	Roughly made sketches of each pattern.	Frame.	1	8	7
2		Ram.	1	5	2
3		Slide for ram.	1	3	2
4		Gibs for ram.	2	–	–
5		Quick return.	1	1	1

This record is kept in pencil to allow changes up to date to be easily made.

The first column contains the consecutive number of each pattern. The second column a roughly-made sketch of each pattern, which greatly facilitates the finding of a piece needed, as the description in the third column is necessarily brief. The fourth, fifth, and sixth columns give the

number of patterns to each part, the number of loose pieces, and the number of core boxes.

This may look a little complicated, but it only needs a little attention once, and our clerical labor is finished. Whenever, after the pattern or any part is needed, whether it is known by number, by name, or only by general appearance, this list furnishes complete data for identification of all its parts.

Upon each pattern, before it is varnished, is stenciled a legend, thus, for the "Slide of the Ram:"

S. No. 3.
3 pieces A. B. C.
2 Core Boxes. Z. X

Being varnished, this record is indelible and always present. Metal numbers, S. 3, are added, that the symbol may appear on the casting. The corresponding loose piece is stenciled S. 3. piece A., or the core box, S. 3. core box X., etc., and so for all the other patterns, pieces, etc. Hence, wherever the pattern is, the record of all its corresponding parts is at hand for reference, and is intelligible to any one, or any piece, no matter how trivial, has an indelible mark that enables us to place it at once.

It has been suggested that by not marking pieces and core boxes by letters, a, b, c, etc., the legend would be rendered much simpler, the legend above becoming merely

S. No. 3.
3 pieces. 2 core boxes.

each piece and box being simply stenciled S. 3, showing thereby that it belongs to pattern No. 3 of machine S.: that is, the 13-inch slotter.

This, however, requires the counting of the number of pieces, etc., and the identification is less certain, while if any core box is to be used for more than one pattern, the necessary instructions become somewhat uncertain.

It has been customary also to stencil the word "Face," not on all the planed surfaces, but on those that particularly need to be clean, that the foundry may be reminded where to be more careful. Naturally, the use of 2 S, 3 S, etc., for other sizes of slotter, or L, 2 L, etc., for different build of lathe, etc., will occur to the user. It is believed that a little attention given to some such system as this, especially for standard machines, gives a record of easy reference and a means of bringing order out of the chaos common in too many pattern lofts.

In regard to the economy of manufacture, as viewed in the pattern, there are so many facts and circumstances entering the problem that I shall touch upon but a few instances that point the direction in which to turn our attention.

1. The economy in the pattern itself, that is its cost in labor and material: this economy should be governed by the number of castings we expect to obtain from it, it being evident that the thought and labor justified and economical in the production of a number of machines would be extravagance where but a few castings are to be produced.

In the latter case the original cost of the pattern is a sensible percentage of the total value of the product, and to reduce this as much as possible, we should confine our designs to straight lines and flat surfaces,

curves and warped bodies being expensive in both time and labor. The pattern can be roughly made, with little provision for warping, as few ribs and fillets as possible are desirable, with few and plain cores, it being generally economy to sacrifice appearance, to be lavish in metal, and ignore many points, though not those of efficiency and stiffness in the final machine.

When the pattern, however, is expected to be duplicated many times, true economy of construction calls for much thought and care, and frequently very elaborate and costly patterns are the cheapest in the end. It pays to build up rings and gear wheels of many parts, that time may not warp them nor rough usage so dislocate faces and parts that the resulting castings are scanty in metal in one part or require excessive finish in another. We should now consider closely how the casting is to be handled, both in finishing and in erecting, cutting down turned and planed surfaces to the smallest allowable limit, and not be afraid of using small and numerous cores where your judgment bids you. Excessive amounts of finish on bright surfaces can frequently be curtailed ; and in other cases where cored round holes are horizontal, and the core therefore liable to shift or rise in the molten metal, we may properly add an extra amount of metal, that the requisite size may be assured, despite accidents.

It is frequently advisable where cored holes are in line one with the other, to use one long core passing through both bearings rather than two smaller ones, as we are thus assured that the holes in the resulting castings will be in line, thus saving the cost of careful setting of the piece, and the long and difficult boring that would be necessary to obtain the required dimensions.

In other cases, such as in long holes, where it is not necessary that the running shaft should bear the entire length, it is customary to enlarge our core between the bearings, so that we may only be at the expense of finishing the bearings, and not the entire distance, but judgment must be displayed in the use of such devices, for if, as in this instance, the thickness of metal at our command does not allow us to make this recess a very decided one, and the core should shift somewhat in the casting, there is no economy, for we may be chagrined to find that a large part of our boring is just in the rough surface of the recess, and the expense in obtaining a true hole is perhaps more than doubled. If I had the space I could cite many similar instances, emphasizing the necessity of care in the use of our little schemes for economy, and of the study of the various operations, methods of handling and final erection through which the casting is to pass, where the cost of the finished product is dependent on the pattern, but I will merely touch on a point in which much uncertainty is frequently displayed.

Castings are frequently made very thin and light, with a view to save the cost of the unnecessary metal, which is good economy ; but it is not considered that the thinner we make our casting the more difficult it is to prevent it from being badly sprung in cooling, in which case we will have saved a few pounds of cheap iron and necessitated several days of costly machine work to finish it. In all this, I do not mean to decry the effort to save metal by making our castings light, but only to impress the necessity of considering well the effect of each effort to do so.

We have all heard that to avoid this trouble of warped castings it is better to have all parts of a uniform thickness, with heavy fillets between ribs and surfaces; but this rule is not one of rigid application, though that of its true meaning, uniform cooling, is true, as far as my experience extends. For instance, if we have to cast a flat surface, stiffened by deep ribbing, we will find that if the surface is to be planed that it will be cast face down, that the planed surface may be freed from floating dirt; this brings the ribs uppermost, and if to economize metal the ribs be made lighter than the face, they will cool first, and if the resulting casting be of any length, it may be bowed a half an inch, requiring much extra time to true up the face; even if the ribs be made of the same thickness as the face, they will still cool first and bow the casting, since they are nearer the surface and removed from the greater body of hot metal. In cases similar to this, we have obtained the most economical results by cutting down the thickness of the face or body of the casting and making the ribs considerably the thicker, that they may be retarded in solidifying until the metal deeper in sand has begun to stiffen, while $\frac{1}{8}$ inch saved over the larger face amounted to more than $\frac{3}{8}$ inch taken from the ribs. We believe that the same idea can be frequently applied with marked economy in metal and labor.

These instances are to show that, when viewing the economy of manufacture in the pattern, the best economy is obtained by keeping well in mind the subsequent manipulations and probable errors in the foundry, that while we make use of careful coring, recessing of core holes, and light castings and ribs, we may not enhance the final cost by unwise economy.

One word more I would like to add, as to the necessity of accuracy and frequent checking of measurements, as there is nothing more frequent nor more exasperating than errors in the dimensions of patterns. It is not enough to carefully check the sizes on the drawing, but the pattern should be viewed during construction, in imagination, as fitting in the finished machine, thus guiding us to detect possible interferences, and often to discover that our patterns, while correct in dimensions, are actually reversed or upside down; and whenever possible, all patterns of parts fitting one into another should be kept back from the foundry until all are finished, so that they can be placed together as they belong, and the dimensions checked independently of the design. Only by unremitting care can we thus, in complicated machinery, obviate the occurrence of annoying errors.

PROPOSED CONSTRUCTION OF A RAILROAD EMBANKMENT TO BE SUBMERGED.

By Lawson B. Bidwell, Member of the Boston Society of Civil Engineers.

[Read April 17, 1889.]

I think it has been the custom here more often to consider works which have been completed, and point out the difficulties which have been overcome, than to take up those which are contemplated. In the first the gain to the Society would without doubt be greater than in the

second, and yet I think as we often arrive at more sound conclusions, and new methods are suggested to us simply by talking over work we are doing or are to do, so it is especially profitable (where the work is of such a nature that it is proper to do so) for any member to bring here the problem he has to solve and invite suggestion or criticism.

For a storage reservoir there is now being built near the village of Sodom, in the town of Southeast, in Putnam County, New York, a stone dam of sufficient height to flood about one and one-half miles of the New York & New England Railroad track, and it was considered more economical to swing the line from the lower edge of the valley up into a rocky hillside than to raise the track on its present location. By arrangement with our people, engineers in the employ of the city ran a line, and made a profile on the centre line and an approximate estimate of quantities. I have always thought it best for a railroad company to have its own engineers control its work, not only in general, but in all matters of detail, and if we built the road, an estimate of cost would be the basis for an award of damage; therefore I called for cross-sections, and a more careful estimate of quantities. This work was done by the city engineers, who sunk various test pits, and took soundings, and made new estimates. Conferences were had, but no agreement then concluded, and after a change in the law affecting the matter, we appeared before the Commissioners of Appraisal. Estimates of the cost of this change were made both by us and by the city engineers, and a very large difference between them was to a considerable extent due to a difference in construction. My claim was that the city should give us a sum of money which should give us a roadbed as stable from the first putting on of our trains as our present roadbed, and one as safe and convenient for our men who are to keep it in repair, and as safe in all respects for our trains. It will be seen at once that this called for a much more thorough method of construction than is usual in building railroads, as such works invariably overrun the estimates, and thus it becomes at the last simply a struggle to get the rails down and trains running, and trust to a careful watching of the masonry and patching up the roadbed, and possibly a future rebuilding of the masonry. It is quite a different thing to make an estimate of cost which shall determine the amount which you shall receive to make a change in the line like the one proposed, and which change you are obliged to make in a given time, and in a safe manner, from making the usual estimate to get a fair approximation to the cost, to judge whether it is expedient to build, and could only be made satisfactorily by a well-defined method of doing the work. With this view I made a careful inspection of the ground, noting particularly the character of the rock and overlying earth, and noting from the profile and estimates of quantities the places and distances to which the material would have to be moved, and the method of construction was determined and the work arranged in the following order: On the north side of the present embankment from stations 58 to 67, as there were but 12 feet to be added, this addition was made entirely of rock. The bank from station 26 + 30 to 36, being in the deepest place over 40 feet in height was made entirely of rock. All other banks were made of earth plated with rock.

First.—Excavate the muck at station 30 for two tracks, the greater part of which will have to be wasted.

Second.—Put in a 10-foot arch for two tracks at station 30 + 15, and culverts at stations 16 + 50, 22, 42 and 60, each $2\frac{1}{2} \times 2$. At station 67 excavate present bank and relay the present culvert, which is $2\frac{1}{2} \times 2$ feet 10 inches, and lengthen it 12 feet.

Third.—Strip earth between stations 35 + 20 and 41 + 82. This earth must be hauled down to the north to the present railroad bank, then across the pond near dam to highway, and be deposited in embankment near station 20, making a haul of about 1,800 feet. Also excavate and strip earth between stations 48 and 58 and make bank and waste on south side of present railroad bank between stations 56 and 67. This leaves about 8,000 yards to waste. For this waste there is no room on the right of way allowed us, and a spur track would have to be laid into the cut, and the earth loaded into cars and moved about $1\frac{1}{4}$ miles. Also strip the earth between stations 43 + 30 and 48, which, with the stripping between 40 + 50 and 41 + 50, will make the embankment between stations 41 + 35 and 43 + 30.

Fourth.—Excavate rock between stations 35 + 20 and 41 + 82 and place it for two tracks for embankment between stations 26 and 35. When the bank is near to the arch the rock will have to be carefully placed over the whole length of the arch, say for 6 feet deep and 16 feet wide.

Fifth.—Excavate the rock between stations 43 + 50 and 53, finishing the embankment between stations 26 and 35 and the rock plating between stations 15 + 80 and 24 and between stations 41 + 35 and 43 + 30 and between stations 58 and 67, and on all these slopes the rock must be placed after being dumped; and where the plating is on the north side of our operated tracks the material would have to be swung across and placed with a derrick. At the foot of all plating a step is to be made in the earth.

Sixth.—Break stone and fill in all interstices on the embankment from station 26 + 30 to station 36 and where the bank is of rock for the second track.

Seventh.—Furnish and put in two switches and frogs, one at each end of the change, and furnish new rails and fastenings and ties, and lay track from station 4 to 67, 6,300 feet.

Eighth.—Ballast from station 4 to 72 for double track, and raise the grade from station 62 to 70, which raising must be made in successive lifts of 6 inches each, and track continually surfaced for passage of trains.

Ninth.—Surface the tracks twice and remove switches and all track material.

Tenth.—Take up 14,000 feet of fence and rebuild on new line 5,000 feet. In the same way the quarry from which the stone for masonry would have to be taken, and the freight and switching and hauling to the work were given. I have wearied your patience with this detail not only to show that we looked into the matter thoroughly, but also to give what I conceive to be the only method of making an estimate worthy of confidence, and I insisted at the hearing that any prices placed on the estimated quantities, and any overhaul made simply from air line dis-

tances from the profile, was not allowable, unless the prices were such as had been paid for work under exactly similar conditions. My estimate was based on making the embankments of a width of 26 feet at full grade or 30¼ feet at subgrade which was 1½ feet below full grade. Slopes on earth banks 1½ to 1. Rock plating on new banks 4 feet thick at a right angle to slope, and on the old bank the additional width for one track is made of rock as mentioned and generally of a slope of 1½ to 1, and on rock banks a slope of 1¼ to 1. We allowed for one-half swell for space occupied by excavated rock over the cross-section quantities in the cuts. The breaking by hand of rock to fill the interstices on the top of rock banks was estimated on the 30½-foot widths at one dollar per lineal foot of double track. The laying of track was estimated at $400 per mile for each track, and the cost of the two surfacings over the 1½ miles, $522. On all material hauled over 800 feet an additional price for overhaul was allowed. This matter of overhaul is of very considerable importance to the contractor, for while his horses might keep in good condition where there was but little overhaul, or even if there was a large quantity to be hauled 1,000 or 1,200 feet, the same horses would be overworked on a haul of 2,000 feet, as their periods of rest do not come often; and the character of the work, whether commencing a fill at the edge of a cut, and making before an overhaul distance is reached an average haul of 400 feet, or having the material so distributed that much of it is hauled 800 feet before meeting the overhaul price, would make a difference in the price per yard for which it could be moved.

Taking the work in the order named: *First* Excavating the muck, which varies from 6 to 12 feet deep and rests on hard pan or compact gravel. This is an accumulation of many years, caused partly by a narrowing up of the gorge by points of rock projecting from the sides, but principally from a wooden dam. The soundings indicate that the rock and overlying hard pan have a downward slope towards and to the dam, then the channel drops abruptly. Our opponents, both engineers and contractors, claimed that it was unnecessary to excavate this muck, and that a small allowance of rock only should be estimated for what muck would be crowded out and what would be compacted in making the bank; and that with a bank made in this way it was safe to put the culvert on what appeared to be a step in the west side of the ravine, from 12 to 15 feet above the lowest hard pan under the bank. My claim was, that the best construction called for an excavation of the muck before the bank was made, and that the culvert should be put at the lowest point, and that it was the more essential from the fact that there was a strong downward incline in the bed of the stream; and although it might be admissible to place the culvert on a higher level, provided the muck was removed, the culvert should be in the lowest place, and be founded on the rock. At a conference with the engineers of the aqueduct commission, to endeavor to arrive at a specification for the work, and to bring our disagreement down to prices only, I stated the matter in this way, but the estimates made by our opponents were not changed.

Second. Stripping theearth from the rock and making the earth core of such banks as were to be made of earth. At the west end

of the work, where there is no rock excavation, although near there rock is in sight, the material is a heavy clay and loam. On the balance of the work east of the large bank the rock varies from appearing at the surface to 12 feet below, and the overlying material is composed of pebbles similar to the finely disintegrated rock and coated with clay. This will stand when dry in excavation nearly perpendicular, but in water flats down to a slope of two or two and one-half to one. It is evident that it would be impossible to make a bank of from 10 to 16 feet in height of this material to a slope of one and one-half to one with anything like a uniform coating of rock in any other way than to make it in layers. and plate each successive layer, and when the water was raised about it that it would not retain its proper form unless the rock plating was laid much closer than it would be by simply dumping. The estimates of our opponents were based on making these banks, which were to be plated, by running out a dump in the usual way for dry work from the material as it would most conveniently come from the cuts; that is, dumping the rock in with the earth as the bank went along, and making the plating only by dumping rock off the sides. This could not have been done with the slopes of one and one-half to one without an expenditure of a very considerable labor in working down and placing of the plating, which was not allowed for in the prices, and although this construction might answer for a dry bank, or for a bank made by dumping the material into water, it is quite a different matter to make a bank in this way dry, and afterwards bring the water about it. I have had a great deal of trouble in one case where a water-course was changed by blasting out for the new channel a spur of rock, which material was used to make the lower part of the railroad across the old channel, the upper part being made with earth. We had finally to lay next to this rock bank a wall in cement to retain the earth above. It was also claimed by our opponents that an earth core with a slope of $1\frac{3}{8}$ to 1, plated with rock simply dumped, or with a very little moving with bars (the price would not indicate anything but dumping) 4 feet thick, at a right angle to the slope, making, it was claimed, a plating of $6\frac{8}{10}$ feet, as it measured that on the horizontal, and with a width for single track at subgrade ($1\frac{1}{2}$ feet below the rails) of 14 feet, making $10\frac{1}{2}$ feet at base of rail, was a safe and proper construction, and this on a bank of more than 40 feet in height, and flooded to within $4\frac{1}{2}$ feet of the base of rail, and only this width showing for a distance of about 900 feet. In the section which accompanied this estimate the width of the earth core at subgrade was practically a point. How the earth was to be so shaped and plated without a large amount of extra handling we were not informed.

Third.—Making the rock bank between stations 26 and 35.

In making this part of the estimate, as well as the rock plating, the question arises as to what shall be allowed for the swell of the rock. I think this is partly affected by the size of the broken rock, but more by the character of it. A very considerable part of the rock to be excavated is a sand stone, which near the surface at least disintergrates on exposure to the air, and in breaking there will probably be considerable fine material, and much of it will not show sharply defined edges. We

estimate on one-half swell or one-third voids. I think this must always be an element of uncertainty. Then as to the slope the rock will take by dumping, and as to what slope when surrounded by water, as this is to be, will be safe. Judging only from recollection of the appearance of rock banks when made by dumping, I should say that it would hardly assume so flat a slope as one and one-quarter to one, without some labor in working it down with bars, but on the ground a slope always appears more steep, and the form a less stable one, than the same would show, when platted in section. I presume in this case, and with the rock taken out with high explosives, the swell may be two-thirds, and that some working down of the rock will be required to bring it to one and one-quarter to one slope, and that such a slope will be sufficient for stability.

As to the culverts, I think there is no economy in laying them dry in any case. It is unfortunate that in almost all original railroad construction, for smaller culverts, almost anything is considered good enough; a trench drain, a cement drain tile with the ends exposed to the frost, with no parapets, or rough stone from the cuts piled together without dressing or bond. The fact that many highway culverts laid with coarse boulders and carelessly bedded stand fairly well has, I think, led to the idea that any stone piled in dry are good enough, but that they *do* stay is due, I think, to the stone being large and heavy and the highways over them so shallow as to wash away and relieve the pressure before the stones are disturbed.

To make good dry work requires better shaped and larger stone than when laid in cement; neither does there seem to be economy in corbeling out the walls and using thinner covers on the smaller culverts, for the corbeling amounts to nothing unless the corbels are as good stone as the covers and carefully fitted. It is cheaper generally to get thicker covers and span the whole opening. Neither do I like to have the paving extend under the walls, for it is better to bed in the earth larger stone for the footing. In a soft or sandy bottom the best way is to use for paving stone as good as the covers, long enough to pass under the side walls. As to the culvert at station 67, which is about 2½ feet wide by 2 feet 10 inches deep, and laid dry, of fair stone in the side walls, but with rough and irregular covering, and under a bank of 30 feet high, I thought the only safe way would be to excavate from the track down by curbing, and relay it properly in cement, as there is every probability that when the bank is saturated the earth would pass through the openings between the covers and cause trouble, and so estimated. On studying the matter since I have concluded that it would be much better to avoid disturbing the old bank, which is well compacted, and shall put a brick lining of about 20 inches high, of 4 inches thick, next to each side wall, and rest on these side walls of brick an arched cast iron cover, one inch thick, cast in sections of 2 feet long, and pack in full over this arch with the best of cement mortar. Our plans now contemplate making banks of earth of not over 17 feet in height, and there will be but a small part of any one bank which will be of this height, and make them of layers of not more than four feet in thickness, and carry up a rock plating of 3 feet thick, measured at a right angle to the slope, which

is to be one and one-half to one; no spaces to be left between the rock core and the plating, and all the interstices in the plating to be chinked full and in such a manner as to remain in place. The large bank of about 40 feet in height to be made of rock, with a slope of one and one-quarter to one, and a width of embankments of $30\frac{1}{2}$ feet at sub-grade.

We had over this award a long controversy, and on our side the benefit of such experts as our President, Mr. FitzGerald, Messrs. L. A. Taylor, J. W. Ellis, Wm. E. Worthen, J. J. R. Croes, A. M. Wellington, W. Howard White, W. Hegeman, Heman Clark and Edward W. Serrell. The testimony in the case covers 1,500 pages of print, and whatever the outcome, it was certainly a satisfaction to me to be supported by the testimony of men of such experience and so well and favorably known in the profession.

Some of the most important points now to determine are: *First*, the best thing to be done with the culvert at station 67. On this we think we have adopted the cheapest plan, which will give sufficient water and make it safe.

Second If the banks to be plated are made one and one-half to one slope, and made with the material I have described, which flats to about two and one-half to one in the water, what thickness of plating will be required on a bank 17 feet in height, and how thoroughly should the interstices be filled, and how should the bank be made?

Third. The area necessary for a culvert at station 30 + 15 when there are about 17 acres flooded on the side opposite the reservoir, and a water shed of about four square miles, and with a bank made of rock.

Fourth. What the increased bulk of the excavated rock over the solid rock will be when placed as above described, as it materially affects laying out the work.

As to the classification of work like the above: With the most careful examination and consideration, there are always some changes from the general plan which must be made as the work progresses, and it is much easier for the engineer to arrive at a fair allowance for such changes when a price is fixed on each kind of material, and as the work progresses there is less question as to the amount to be allowed on the usual monthly estimates. Generally I think work will cost more when let without classification, as no contractor will take risks without being paid for them. On the whole I prefer a classification on the items of work which differ the most in price.

A word as to contracting: When we have a work of any magnitude to let we inquire more particularly about the pecuniary responsibility of the contractor, but not so carefully as to the kind of work he does or the subcontractors he employs. All large contractors have a family of subcontractors who follow them about, and the engineer usually has more to do with them as to all details than he does with the principal contractor, and they frequently give him more trouble.

In this connection a short statement of the construction of a bank made in the water at Whaley Pond in Duchess County, New York, in the extension of our road to Fishkill may be of interest. About twelve years before there was a large amount of work done on this portion of our line, but owing to financial difficulties the work was stopped. As is

usual in such cases the difficult points were avoided as long as possible, and coming later we found many places which taxed both brains and purse heavily. Among these was this opening, where our lines crossed a part of the pond, which at that place was originally about 1,600 feet in width, and the original profile showed about 12 feet of water, and the deepest soundings to hard bottom about 35 feet. Our predecessors filled all but about 600 feet by taking out a hard, clayey cut at the east end and a lime-rock cut at the west end. When our turn came we went at it with a good deal of vigor, borrowing from this earth cut, and ran a steam shovel through the fall and winter. We also borrowed from the rock cut at the west end, about 26,000 yards. When all this was done and we had acres of muck raised about us, our dumps would stay up for a week, and progress 20 or 30 feet, and then go out of sight. We had still an opening of about 400 feet, which seemed impassible except by a floating bridge. We then brought hard pine piles of 60 to 70 feet in length from New York and hauled them and the timber about 10 miles over the hills, built a driver for driving 14 feet ahead of bearings, and drove about 70-foot piles, and generally drove on top of them by doweling others of about 40 feet. When the resistance appeared sufficient, we capped them and went on, and finally made 450 feet of trestle. As soon as we commenced to run over it, some of the piles came up about four inches. None settled so as to cause serious trouble from the weight of our trains, but we had continually to work upon it, and the surface was bad, and it was always out of line. After our business over it was fairly started, we commenced to fill with gravel from a hill about 1½ miles away, and kept a gang of six or eight men constantly at work on the trestle to get our trains over. The bank would roll, and twist and turn very slowly in all directions like a huge serpent. We ran around curves of about 300 feet radius, and up and down grades of probably 150 feet to the mile, and cleaned up all the old timber on the road, and a number of train loads of new ties for crib work. As we dumped the gravel, a single train load on one side would sometimes throw the bank to that side, then we would balance by dumping on the other. By the packing of the gravel about the piles, they were slowly but irresistibly carried down with the filling, generally one at a time, and starting ten or fifteen minutes after dumping. We built cribs about each bent under each cap, and jacked and blocked up the floor of the trestle, continually moving from one bent to another, and throwing the track sideways when necessary, until we had as much or more height of crib as the original length of piles; and as the piles seemed to go nearly perpendicular, I suppose the bottom of them when we finished were 225 feet below grade.

With the exception of a settlement of about ten inches in 1883, I think there has not been much trouble with the bank, and I do not anticipate any as long as a single track only is used. If it is ever double-tracked there may be some movement.

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HIGH-SERVICE SYSTEM OF THE BOSTON WATER-WORKS.

BY JOHN A. GOULD, JR., MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read May 15, 1889.]

The Cochituate works were built in 1848 to furnish the water supply for the city of Boston, and the distributing reservoir was located in the town of Brookline with its high water line at grade 124 feet above tide-marsh level. All the territory within the limits of the city at that date could be supplied from these works, and wholly by gravity. The most elevated sections were Beacon Hill in the city proper, Telegraph Hill in South Boston, and Eagle Hill in East Boston, in which the highest door-sills were at grade, 106, 107 and 82 feet respectively. The supply in these districts could hardly be called satisfactory, but water would enter the second stories of all the houses: and as each district had a local distributing reservoir to equalize the day and night pressure on the mains, a virtue was made of necessity during the 20 years that this condition of things lasted.

In January, 1868, Roxbury was annexed to Boston. The annexed territory contained an area of 600 acres above the 70-foot contour, and 1,100 acres above the 60-foot contour, which was afterward considered the dividing line between a satisfactory and an unsatisfactory supply from the low service works. Measures were soon taken to furnish a supply for that district by pumping, which resulted in the building of a pumping station on Elmwood street, in Roxbury, containing two pumps made by the Boston Machine Company, each capable of pumping 1,800,000 gallons in twenty-four hours, and the erection of a stand-pipe on Fort avenue in Roxbury. This stand-pipe was 5 feet in diameter and 80 feet high, with its base at an elevation of 158 feet above water-works base. The stand-pipe, which was made of wrought iron, was inclosed in a brick tower.

These works were put in operation on February 25, 1870, and on June 4 of the same year the high service was supplied to Beacon Hill through the old 30-inch low-service main that was laid in 1848. Although this gave an increase of about 50 pounds per square inch in the pressure on this pipe, and the pipe had been in use twenty years, there were but few minor leaks occasioned: the two principal ones were caused by the 30-inch gates bursting

This pipe was used for this purpose for four years, when a new 20-inch × 16-inch main was laid, and the 30-inch was again used for the low service. South Boston was also supplied temporarily through the 20-inch line in Boston and Dorchester streets that was originally used for the low service.

This shows that a large factor of safety in pipes is sometimes of value.

On January 3, 1870, the territory to be supplied from the high-service works was largely increased by the annexation of Dorchester, which contained about 2,400 acres above grade 60.

The stand-pipe soon became too small to accommodate the increased consumption, while depending on the present pumping machinery, and Parker Hill reservoir was built in 1873–74 to take its place. This reservoir holds 7,000,000 gallons, and its high-water line is at grade 219.

In January, 1874, West Roxbury and Brighton were annexed to Boston; the former containing 6,870 acres above grade 60, and the latter 1,000 acres. The area of the high-service district had now increased by annexation and enlargement from 760 acres, when the Roxbury pumping station was built, to 11,500 acres, and it was evident that an increase in the plant was necessary. In November, 1875, the City Engineer, Mr. Jos. P. Davis, reported to the Water Board, recommending the abandoning of the existing pumping station on account of its size and location, and the construction of a new station near Chestnut Hill reservoir, with a main distributing reservoir on one of the neighboring hills, and also an additional reservoir in West Roxbury. The latter and Parker Hill reservoir were to be distributing reservoirs, receiving their supply from the main reservoir, and each commanding the territory in its immediate vicinity. As several years would elapse before these works could be completed, he recommended that temporary works be built to supply Brighton. This district was so remote from the other portions of the high service that it was not advisable to connect it by a pipe line until the main works should be built. The latter portion of his recommendations was immediately acted upon by the City Council, and the Brighton works were built and in operation on August 10, 1876, at a cost of about $8,000.

These works, although called temporary, were in operation for eleven years and five months before they were supplanted by the new works at Chestnut Hill.

An interval of nearly ten years intervened before any definite action was taken by the City Council toward the construction of new works, although annually advised to do so by the City Engineer and the Water Board. As a measure of partial relief, a 3,000,000 Worthington pumping engine was placed in the Roxbury Station in 1878, and this pump was in use over ten years before the new works relieved it.

Finally, in December, 1884, an appropriation of $766,000 was made by the City Council for works to be built on the same general plan as recommended by Mr. Davis and indorsed by Mr. Henry M. Wightman, who was City Engineer at that time. They were finally built, and the details designed under the direction of the present City Engineer, Wm. Jackson.

In June, 1885, while the detail plans and specifications for the new works were being prepared, a Commission was appointed by the Mayor to investigate the whole subject of new high-service works, and ascertain if the

scheme of works about to be begun was the best that could be devised. This Commission consisted of L. F. Rice, C. E., as chairman, and Messrs. S. B. Stebbins and L. F. Morse. The consulting engineers engaged were Messrs. Jos. P. Davis, A. Fteley and E. C. Clarke.

A report was made in September, indorsing the original scheme in all its details, with the exception of the location of the proposed West Roxbury reservoir. The site recommended by the Commission was in Roslindale instead of on Clarendon Hills.

The system of works as built may be briefly outlined as follows:

A pumping station near Chestnut Hill reservoir with its screen and connection chambers, a 30-inch force-main 5,800 feet in length to the principal reservoir on Fisher Hill in Brookline, Fisher Hill reservoir, with a capacity of 15,000,000 gallons, and a supply main from Fisher Hill to Parker Hill reservoir which consists of 6,800 feet of 30-inch and 8,000 feet of 24-inch pipe. Parker Hill reservoir is connected with the distribution by a 24-inch main, which is gradually reduced to 20, 16 and 12-inch mains.

DETAILS OF CONSTRUCTION.

The buildings consist of an engine room 84 feet 10 inches × 64 feet 8 inches, with a basement; a boiler room 79 feet 10 inches × 56 feet 2 inches; a coal room 65 feet 4 inches × 62 feet, connected with the boiler room by an extension 43 feet 8 inches × 19 feet 10 inches; also a screen and connection chamber.

The screen chamber is a circular structure located about 30 feet west of the pumping station. It is so located that at some future time it will form one corner of the pumping station if the latter is enlarged. The chamber has a concrete foundation and is built of rubble masonry laid in hydraulic cement, and the inside walls are faced with bricks.

A brick conduit 48 inches × 54 inches in section, connects the chamber with the Cochituate conduit, which is about 50 feet distant. A 36-inch iron pipe connects the chamber with a 48-inch pipe, which runs from the terminal chamber of the Sudbury River conduit to the effluent mains from Chestnut Hill reservoir. By this connection, water can be drawn directly from the Sudbury conduit, or from the reservoir by letting it back up from the effluent pipes just mentioned. A third connection, from the screen chamber to the reservoir direct, has been designed. This is through a 48-inch pipe, laid at a grade 5 feet lower than the two other connections, which will be useful if the water in the reservoir should ever become unusually low. At present this pipe has been laid only as far as the centre of Beacon street, as there is no immediate necessity for its completion.

The flow of water from these connections is controlled by iron sluice gates. Four sets of double grooves are built into the masonry to receive stop-planks or screens when necessary.

The chamber is covered with an iron floor, and is surmounted by a circular wooden house.

The screen chamber is connected with the pump wells by a brick conduit 4 × 5 feet in section. The foundation and side walls of this conduit are built of concrete, faced with 4 inches of brick, and has a 12-inch brick arch.

There are three pump wells in the basement of the engine house; two

of them, which are now in use, are each 18 × 10 feet and 16 feet deep: the third, which was provided for a future pumping engine, is 21 × 10 feet and 16 feet deep.

These wells are connected with the conduit by gateways, which are controlled by 3-foot × 3-foot iron sluice gates.

In order to provide for the possible extension of the engine room for a fourth pumping engine, a gate opening for a proposed pump well has been built into the foundation wall on the west end of the building, and the bottom of a foundation wall between the present building and the screen chamber has been built as high as the spring line of the conduit, so that an extension to the present building can be built at any time without interfering with the operation of the present pumping plant.

A foundation of concrete extends under the pump wells; the inverts are covered with 8 inches of brick: the side walls are built of rubble masonry faced with bricks, and the division walls are brick masonry 3 feet thick.

Each well can be emptied through a 12-inch iron pipe drain, which also receives the waste water from the condensers of the engines.

The basement has a Portland cement concrete floor and contains a lathe, planer, drill, etc., being used as a repair shop.

The pumping machinery consists of two Gaskill horizontal compound engines, built by the Holly Company, of Lockport, N. Y.

The high-pressure cylinders are 21 inches in diameter, the low-pressure cylinders 42 inches in diameter, the water-plungers 25 inches in diameter, and all have a stroke of 36 inches. The plunger displacement is 302 gallons per revolution, and a speed of about 18.5 revolutions per minute give the guaranteed capacity of 8,000,000 gallons per 24 hours.

The foundation of each pump consists of a solid block of American cement concrete 14 feet 5 inches in thickness, and on each foundation are built four brick piers 6 feet 8 inches high, surmounted by a granite coping for the engine bed, 12 inches in thickness.

The engines and pumps are secured in position by $1\frac{3}{4}$-inch bolts, which are built into the entire depth of the brick foundation. These bolts were set inside of 3-inch gas pipes, so they could be adjusted to fit the bed plate of the engines without any trouble. The force main from each pump is 24 inches in diameter, and they unite outside of the building in a 30-inch pipe, which extends to the Fisher Hill reservoir. Branches and gates have been placed in the force main, so that a third and a fourth engine can be connected with the force main without stopping the pumping. Branches have also been located to connect with a second force main.

Steam is furnished by two horizontal tubular steel boilers, 78 inches in diameter and 18 feet 5 inches long. The shell is $\frac{7}{16}$ inch thick, and each boiler contains 151 tubes, 3 inches in diameter. Each boiler contains 2,171 square feet of heating surface and 49 square feet of grate area.

The grate area has been reduced temporarily to 38.5 square feet by bricking up 9 inches on each side. These side walls will probably be removed when the boilers are run to their full capacity. A feed-water heater is placed in the smoke flue between the boilers. It is made of 80 brass tubes, each $2\frac{1}{2}$ inches in diameter and 15 feet long, supported by racks on a portable carriage. It has a heating surface of 931 square feet.

By means of this heater the evaporation in the boilers is increased about one-half a pound per pound of coal. The boilers are fitted with rocking grates and a steam damper. A steam pipe 10 inches in diamater conducts the steam from the boilers to the engine room, and 6-inch branches connect the engines with the main steam pipe. The smoke flue from the boilers to the chimney is built of brick, and is carried under the floor of the boiler room. The boilers can be fed by feed pumps on the Gaskill engines or by an independent feed pump. The steam for heating the buildings is taken from these boilers, and the condensed steam is trapped and forced through a meter, and thence returned into the boilers by an automatic force pump; by this means the amount of steam used for heating can be deducted from the amount evaporated, and only the net amount charged to the engines in calculating the duty.

The boilers and heater were built from designs made in the office of the City Engineer.

The engines and boilers were tested in August and September of last year: the method employed was described by Mr. J. E. Cheny, Assistant City Engineer of Boston, during the discussion of duty trials at the January meeting of this society. The results obtained were briefly as follows: A duty of 103,347,500 feet-pounds from 1,100 pounds of steam from and at 212 degrees, was developed by engine No. 1, and a duty of 105,164,600 feet-pounds by engine No. 2. The best result obtained from the boilers during the trials was an actual evaporation of 10 pounds of water per pound of coal, or an equivalent evaporation of 11.57 pounds from and at 212 degrees.

The chimney is located in the extension of the coal house. It is 150 feet in height above the floor of the boiler room, and the foundation extends to solid earth at a depth from 25 to 26 feet. The foundation is 27.8 feet square at the bottom and is stepped in to 20 feet square at the grade of the bottom of the flue where the brickwork begins.

The foundation is of Portland cement concrete to a height of six feet above its lowest point, and the upper portion is of rubble masonry, laid solid in American cement mortar. An iron door has been placed in the chimney at its base for the removal of soot, and an opening for a second smoke flue has been built and bricked up until needed. The chimney is drawn into a circular form above the openings for the flues. The outside shell of the chimney is 15 feet in diameter at its base and is 28 inches thick: it has an outside batter of 0·288 inches per foot, and its thickness is gradually reduced to 16 inches at a point 96 feet above the floor. The flue is circular: its inside diameter is 5 feet 6 inches, and its wall is 12 inches thick at the base and 4 inches at the top, which is 20 feet below the top of the outside shell. The chimney has a cast-iron cap made in sections and is fitted with a double line of half-inch copper lightning rods. A ladder made of three-quarter-inch diameter iron rods is built into the brick masonry inside of the flue.

In building the chimney the core was first carried up about 5 feet, the height of one stage. A cross frame with an eyelet in the centre, to which the line of a plumb bob was attached, was adjusted over the centre point in the bottom of the flue and clamped in position. There was a pivot over centre on the upper side of the frame, to which a sliding rod was attached

and about which it could be swung. The radius of the outside of the shell was calculated for the given elevation and the radial rod set at the proper length. The work built on the preceding stage was checked by a straight edge and a plumb rule, to which a strip with the proper batter had been screwed. The plumb bob used weighed 4 pounds, and there was no difficulty in setting the frame with 150 feet of line if the entrances to the flue were closed in windy weather.

The coal house contains four bins, and will store about 1,000 tons of coal. The bins are made of spruce plank 6 inches wide, laid flatwise, and each course thoroughly spiked to the preceding courses.

The coal is shovelled from the cars, standing on the side track, into a pocket that has a bottom which slopes toward two sliding doors. These doors are opened by levers, and the coal runs into the hoisting buckets, in which it is raised by a hoisting engine to an elevated platform outside of the coal house, and is then dumped into the bins from elevated runs built over the division of the bins. Platform scales are provided, by which the coal can be weighed in the barrows. The coal pocket holds about 10 tons. The principal advantage in using it is in being able to keep the hoisting apparatus constantly going while the cars are being shifted. The coal is brought from the bins to the boilers in iron cars that run on iron rails. Turntables are placed in front of each bin and the track runs over platform scales.

The foundations of the building are made of rubble masonry laid solid in cement mortar and are from 8 to 17 feet deep. They are 4 feet thick at the bottom, and the thickness at top varies from 2 feet 6 inches to 4 feet to correspond with the thickness of the walls of the superstructure. The stone came from quarries in Brighton.

The location on which the pumping station is built was originally a meadow and was filled to a depth of from 6 to 14 feet with the surplus material from the Chestnut Hill reservoir. The foundations were carried below this filling to hard bottom.

The superstructure of the building has an underpinning of granite with eight cut faces. The exterior walls on the front and two ends are built of broken ashler from Milford quarries, with heavy trimmings of Longmeadow freestone, and are backed with brick masonry. The rear wall of the building has a brick face. The interior walls in the engine room are finished with face brick; the ceiling is sheathed with cypress and the floor is birch. The roofs of the buildings are supported by iron trusses, which are covered with 2½-inch white pine and slated. The floor of the boiler room is paved with bricks on edge resting on a 4-inch layer of concrete. The floors of the coal house and basement are made of Portland cement concrete.

The height of water in the pump wells is shown by two float gauges. The rods of the gauges are one-inch-square brass tubes and are graduated to read in feet and hundredths above water-works base. The graduation is on the rods and the indicator is stationary. This brings the reading point directly before the eye at all times.

There are two mercury gauges connected with the force mains, and they are graduated to read in equivalent grades in feet, etc., above water-works base, so the lift by the pumps is obtained by simply subtracting the reading of the pump well gauge from that of the mercury gauge.

LABOR.		Earth and Rock Excavation.			Dimension Stone Masonry.			American Cement Concrete			Portland Cem. Concrete			Brick Masonry in Eng. Foundations etc.			Brick Masonry in Chimney.			Rubble Stone Masonry.		
		Days Work	Rate	Amount	Days Work	Rate	Amount	Days Work	Rate	Amount	Days Work	Rate	Amount	Days Work	Rate	Amount	Days Work	Rate	Amount	Days Work	Rate	Amount
Foreman 1st.		127½	2.00	255 00			Cost of Labor & plant included in brick and rubble masonry in foundations	37¼	2.00	74 50	8¾	2.00	17 50							115¼	3.75	432 19
" 2nd.																				6	2.00	12 00
Boss Mason.														12	4.00	48 00	57	4.00	228 00	62¾	4.00	251 00
Masons.														359¼	4.00	1437 00	197¼	4.00	789 00	362¾	3.50	1269 63
Tenders.														446	1.75	780 50	326	1.75	570 50	915	1.75	1601 00
Blacksmith.																				7	2.50	17 50
Engineer.		40½	2.50	101 25													41½	2.50	103 75	47	2.50	117 50
Carpenters.		8	2.00	16 00				69	2.00	138 00				20½	2.00	41 00	16	2.00	32 00			
Laborers.		923½	1.75	1616 13				358½	1.75	627 38	113	1.75	197 75			126 20			103 20			
Timekeeper.		26	1.00	26 00				10	1.00	10 00				16	1.00	16 00	2	1.00	2 00	21	1.00	21 00
Water Boy.		16¼	1.00	16 25				5	1.00	5 00				11	1.00	11 00	13	1.00	13 00	13	1.00	13 00
Teaming.		82½	3.00	247 50				49	3.00	147 00	13½	3.00	40 50									
TOTAL.				2278 13						1001 88			255 75			2259 70			1841 45			3734 82
MATERIALS.	VALUE.							*			*											
Brick.	$11.50 per M.															3012 00			2841 00			
Roxbury Stone.	1.50 " yd.																			2415 yds.		3622 50
Portland Cement.	2.50 " bbl.										241 bbls.		602 50				10 bbls.		25 00			
American "	1.40 " "							1084 bbls.		1517 60				522½ bbls.		731 50	135 "		189 00	1536 bbls.		2150 40
Six Cut Stone.							2200 00															
Sand.	0.75 per cu. yd.							300		225 00	63 yds.		47 25	135 yds.		101 25	100 yds.		75 00	400 yds.		300 00
Lime.	1.15 " bbl.	Powder		3 50													144 bbls.		165 60			
Water.										12 50			5 00			10 00			10 00			20 00
TOTAL.				3 50			2200 00			1755 10			654 75			3854 75			3305 60			6092 90
PLANT.																						
Lumber.	$16.00 per M.																8 M.		128 00			
Sheeting.				25 00						50 00										Coal 4 tons @ 4.50		18 00
Engine.	1.50 & 2.00 p. day.	40½ days		60 75													41½ days		83 00	47 days		70 50
Steam Derrick.	1.50 " "	40½ "		60 75																47 "		70 50
Derrick.	2.25 " "	Coal 6 tons @ 4.50		27 00													Coal 6 tons @ 4.50		27 00	115½ "		259 75
Tools.				20 00						9 00			3 00						5 00			20 00
TOTAL.				193 50						59 00			3 00						252 00			430 75
		per Cub. yd.		Total.	per Cub. yd.		Total.	per Cub. yd.		Total.	per Cub. yd.		Total.	per Cub. yd.		Total.	per Cub. yd.		Total.	per Cub. yd.		Total.
Grand Total Cost.		Rock & Earth		2475 13	43	39	2200 00	3	49	* 2815 98	5	50	913 50	12	18	6114 45	11	40	5399 05	4	25	10266 47
Value of Work.		Rock 6	50	715 00	25	00	1267 50	3	75	3023 13	4	75	788 50	13	50	6777 00	13	50	6392 25	4	50	10867 50
		Earth 0	75	1344 20																		
Profit.								0	26	212 15				1	32	662 55	2	10	993 20	0	25	601 03
Loss.				415 93	18	39	932 50				0	75	125 00									
Amount of Work done.		110 Cub. yds. Rock. 2068 " " Earth.			50.7 Cub. yds.			807.5 Cub. yds.			166.0 Cub. yds.			502.0 Cub. yds.			473.5 Cub. yds.			2415. Cub. yds.		

* Crushed stone for concrete furnished by the city.
Profits, $2,177.93; losses, 1,473.43; total profit, 1,004.50. Work commenced April 1, 1887; work finished Oct. 28, 1887.

BOSTON WATER WORKS—CONSTRUCTION ACCOUNT—CHESTNUT HILL PUMPING STATION, FOUNDATIONS AND CHIMNEY.

The buildings are lighted by electricity; the engine and dynamo are located in the boiler room.

The superstructure, with the exception of the roof trusses and chimney, was designed and constructed under the direction of the City Architect.

The greater portion of the excavation was done by the city by day labor. The building of the foundations, pump, wells, conduits, chimney, etc., was done by contract. As is customary on all such work done under the City Engineer, a force account was kept, and a record made of the cost of the work to the contractors. A study of the force account shows that 1.34 barrels of American cement were used in making a cubic yard of concrete, in the proportion of one part cement, two sand and five crushed stone, and that 1.45 barrels of Portland cement were used under the same conditions; 0.64 barrels of American cement per cubic yard of rubble masonry, the mortar being one part cement and two parts sand, and that 1.04 barrels cement per cubic yard of brick masonry, exclusive of that in the chimney. In the chimney one-half cement and one-half lime was used in the mortar, Portland cement being used instead of American cement in the upper 30 feet of the chimney.

The force main, after leaving the pumping station, is laid through the city's land to Chestnut Hill avenue, where a 16-foot branch is taken off to supply the Brighton high-service district. Brighton thus receives its supply directly from the pumps while they are in operation, and is the only district so situated. Complaints were made at first of water hammer in the houses in the vicinity that were located on streets where the pipes had dead ends; these ends were afterward connected, and all trouble has been removed.

The force main is laid without summits, except in the wrought-iron pipe on the bridge over the B. & A. R. R. In order to do this a cut of 21 feet was necessary in Fisher avenue. The principal reason for making this deep cut was to enable Brighton to obtain a supply when the reservoir is low. All changes in direction were made with curves of at least 15 feet radius. The pipes in front of the reservoir are so connected that the supply can be sent directly to the city without entering the reservoir. Branches have been placed in the pipe at that point to connect with a second force main and a second supply main.

FISHER HILL RESERVOIR.

On Oct. 7, 1885, a contract was made with Moulton & O'Mahoney, of Lawrence, for building Fisher Hill reservoir with its gate chamber, so that this work was begun about 15 months before the pumping station. The reservoir is built partly in excavation and partly in embankment; it is rectangular in plan, 500 $\times$ 295 feet measured on the top of the inner slope and 423 $\times$ 218 feet at the foot of the slope. The bottom pitches 2 feet from the outside toward the centre, so there is a depth of 20 feet of water in the centre and 18 feet at the foot of the slopes, when the water in the reservoir is at high water mark. The capacity of the reservoir above grade 223, or the foot of the slope is 15,446,000 gallons.

The highest point in the lot on which the reservoir was built was at its centre, and the surface sloped away from the centre in all directions. This summit was practically the centre of the location of the reservoir.

Labor

LABOR	Earth Excavation Days Work	Rate	Amount	Rock Excavation Days Work	Rate	Amount	Rubble Masonry Days Work	Rate	Amount	Brick Masonry Days Work	Rate	Amount
Foreman 1st.	348	2.30	$800.00			$	47	4.00	$188.00	21	4.00	$84.00
" 2nd.	178	2.25	400.50				24	3.00	72.00			
" 3rd.	30	2.00	60.00									
Machinist.												
Blacksmith.	132	2.50	330.00	1	2.50	2.50	80	2.50	200.00			
Brick Mason.										87	3.50	304.50
Stone "							216	3.50	756.00			
Dressing Mason.							45	3.00	135.00			
Stone Cutter.							97	2.75	266.75			
Drillers							62	1.75	108.50			
Teamster	426 / 2033	1.50 / [illegible]	639.00 / 4602.80				129	2.00	258.00	1/2	2.00	1.00
Laborer	1765 / 6479	1.50 / 1.60	2647.50 / 10366.40	16 / 36	1.50 / 1.60	24.00 / 54.40	299	1.75	523.25	144	1.75	252.00
Timekeeper	152	2.00	304.00									
Teaming. One Horse	3366	1.50	5049.00				257	1.50	385.50	1	1.50	1.50
Rolling. Two Horses & Driver	158	4.60	726.80									
Watering. " " "	63	4.60	289.80									
Ploughing. Two Horses	607	3.00	1821.00									
Harrowing " " & Driver												
TOTAL.			28096.80						2893.00			643.00

LABOR	Slope Puddle Days Work	Rate	Amount	Bottom Puddle Days Work	Rate	Amount	Amer. Cement Concrete Days Work	Rate	Amount	Port. Cement Concrete Days Work	Rate	Amount
Foreman 1st.	135	2.50	$337.50	66	3.00	$198.00	40	3.00	$120.00	90	3.00	$270.00
" 2nd.												
" 3rd.												
Machinist.												
Blacksmith.	10	2.50	25.00	10	2.50	25.00						
Brick Mason.												
Stone "												
Dressing Mason.										6	3.00	18.00
Stone Cutter.												
Drillers												
Teamster	105	2.00	210.00	78	2.00	156.00	30	2.00	60.00	73	2.00	146.00
Laborer	1683	1.75	2945.25	602	1.75	1053.50	325	1.75	568.75	993	1.75	1737.75
Timekeeper												
Teaming. One Horse	185	1.50	277.50	150	1.50	225.00	61	1.50	91.50	129	1.50	193.50
Rolling. Two Horses & Driver				36	5.00	180.00						
Watering. " " "				5	5.00	25.00						
Ploughing. Two Horses												
Harrowing " " & Driver				50	5.00	250.00						
TOTAL.			3795.25			2112.50			840.25			2365.25

LABOR	Ballast Days Work	Rate	Amount	Slope Paving Days Work	Rate	Amount	Dimen. Masonry with Quarry Face Days Work	Rate	Amount	Dimen. Masonry Six-Cut Days Work	Rate	Amount
Foreman 1st.	25	3.00	$75.00	98	4.00	$392.00	9	4.00	$36.00	6	4.00	$24.00
" 2nd.												
" 3rd.												
Machinist.												
Blacksmith.				75	2.50	187.50	3	2.50	7.50	2	2.50	5.00
Brick Mason.												
Stone "				323	3.50	1130.50	31	3.50	108.50	18	3.50	63.00
Dressing Mason.												
Stone Cutter.				63	2.75	173.25				13	2.75	35.75
Drillers												
Teamster	135	2.00	270.00	289	2.00	578.00	15	2.00	30.00	7	2.00	14.00
Laborer	298	1.75	521.50	562	1.75	983.50	37	1.75	64.75	25	1.75	43.75
Timekeeper												
Teaming. One Horse	226	1.50	339.00	578	1.50	867.00	30	1.50	45.00	14	1.50	21.00
Rolling. Two Horses & Driver												
Watering. " " "												
Ploughing. Two Horses												
Harrowing " " & Driver												
TOTAL.			1205.50			4311.75			291.75			206.50

LABOR	Laying 36 inch Pipe Days Work	Rate	Amount	Laying 16 inch Pipe Days Work	Rate	Amount
Foreman 1st.	2	3.00	$6.00			
Blacksmith.						
Laborer	14	1.75	24.50			
TOTAL.			30.50			

Cost included in Brick and Rubble Masonry (Laying 16 inch Pipe)

Materials

MATERIALS.	VALUE	Earth Excavation	Rubble Masonry	Brick Masonry	Slope Puddle	Bottom Puddle
Brick.	$10 per M.			66 M — 660.00		
Granite	4.50 & 5.00 Cu. yd.		400 yds — 1800.00			
" - Quarry Face	$20.00 Cu. yd.					
" - Six Cut.	$35.00 " "					
Roxbury Stone	1.00 per perch					
Blue " "	1.00 " load		19 loads — 19.00			
Crushed " "	0.90 " Cu. yd.			5 yds — 4.50		
Ballast.	0.30 " "		64 yds — 15.20			
Sand.	1.80 " "			43 yds — 77.40		
Portland Cement.	2.66 " BBL		2 bbls. — 5.32	8 bbls — 21.28		
American "	1.41 " "		227 " — 320.07	149 " — 210.09		
Water.	2 1/2¢ - 100 gallons	450,000 — 112.50	6,900 — 1.73	4,700 — 1.18	471,500 — 117.86	150,000 — 30.00
TOTAL.		112.50	2261.32	974.45	117.86	30.00

MATERIALS.	Amer. Cement Concrete	Port. Cement Concrete	Ballast	Slope Paving	Dimen. Masonry with Quarry Face	Dimen. Masonry Six-Cut
Brick.						
Granite				141 — 705.00		
" - Quarry Face					37.7 yds — 754.00	
" - Six Cut.						21.2 yds — 742.00
Roxbury Stone				681 — 681.00		
Blue " "						
Crushed " "	560 yds — 504.00	1400 — 1260.00	1860 yd — 1674.00			
Ballast.			295 — 88.50			
Sand.	223 — 401.40	578 yds — 1040.40			10 yds — 18.00	2 yds — 3.60
Portland Cement.		2077 bbls — 5524.82				
American "	801 bbls — 1129.41				35 bbls — 49.35	6 bbls — 8.46
Water.	24000 — 6.00	62,300 — 15.57			1,100 — .26	200 — .05
TOTAL.	2040.81	7840.79	1762.50	1386.00	821.61	754.11

Plant

PLANT	VALUE.	Earth Excavation	Rock Excavation	Rubble Masonry	Brick Masonry	Slope Puddle	Bottom Puddle
Derrick	$1.50 per day			71 days — 106.50	12 — 18.00		
Water Pipe.	15.75						
Harrow.	15.00						15.00
Rollers.		100.00					40.00
Water Cart.		50.00					5.00
Lumber	15.00 per M					1 M — 15.00	
Tools Loss of and Interest on Value		200.00	2.00	5.00		25.00	12.00
Powder			3.00				
TOTAL.		350.00		111.50	18.00	40.00	97.00

PLANT	Amer. Cement Concrete	Port. Cement Concrete	Ballast	Slope Paving	Dimen. Masonry with Quarry Face	Dimen. Masonry Six-Cut
Derrick				98 — 147.00	9 — 13.50	1 day — 1.50
Lumber	3 M. — 45.00	9 M. — 135.00				
Tools Loss of and Interest on Value	6.48	19.85	5.95	25.00		
TOTAL.	51.48	154.85	5.95	172.00	13.50	1.50

Cost and Profit

	Earth Excavation Per Cub. yd.	Total.	Rock Excavation Per Cu. yd.	Total	Rubble Masonry Per Cu. yd.	Total	Brick Masonry Per Cu. yd.	Total	Slope Puddle Per Cu. yd.	Total	Bottom Puddle Per Cu. yd.	Total.	Amer. Cement Concrete Per Cu. yd.	Total
TOTAL COST.	0.35	28559.30	.89	85.90	13.36	5265.82	11.77	1635.45	0.71	3953.1	0.34	2214.50	5.23	2932.54
	Paid Sub-Cont. 0.38	30816	Paid Sub-Cont. 1.25	121.25										
VALUE OF WORK.	0.41	33248.95	1.25	121.25	9.00	3546.00	10.00	1390.00	0.54	3005.64	0.48	3085.92	5.52	3096.72
PROFIT	0.03	2432.85									0.14	871.42	0.29	164.18
LOSS.					4.36	1719.82	1.77	245.45	0.17	947.47				
AMOUNT OF WORK DONE	81095 Cub. yds		97 Cub. yds.		394 Cub. yds		139 Cub. yds.		5566 Cub. yds		6429 Cub. yds		561 Cub. yds	

	Port. Cement Concrete Per Cu. yd.	Total	Ballast Per Cu. yd.	Total	Slope Paving Per Cu. yd.	Total	Dimen. Masonry with Quarry Face Per Cu. yd.	Total.	Dimen. Masonry Six-Cut Per Cu. yd.	Total.	Laying 36 inch Pipe Per Cu. yd.	Total	Laying 16 inch Pipe Per Cu. yd.	Total
TOTAL COST.	7.67	10360.89	1.38	2973.95	9.06	1277.46	29.89	1126.86	45.38	962.11	0.22	30.50		
					4.77	4592.29								
VALUE OF WORK.	7.62	10287.00	2.50	5387.50	7.50	1057.50	22.50	848.25	38.00	805.60	0.27	37.53	0.15	6.30
					3.57	3437.91								
PROFIT			1.12	2413.55							0.05	7.03	0.15	6.30
LOSS.	0.05	73.89				1374.34		278.61	7.38	156.51				
AMOUNT OF WORK DONE	1350 Cub. yds		2155 Cub. yds		1104 Cub. yds		37.7 Cub. yds.		21.2 Cub. yds.		139 lin. feet		42 lin. feet.	

Profits, $5,895.33; losses, $4,796.09; total, $1,099.24; profit on clay, $1,510.30; total profit, $2,609.54.

2,746 cubic yards of clay used in puddle, at $2.30, $6,315.80; 2,746 cubic yards of clay furnished by sub-contractor, at $1.75, $4,805.50; profit on clay, $1,510.30.

Work commenced, Oct. 10, 1885; work finished, Nov. 18, 1887.

BOSTON WATER WORKS—CONSTRUCTION ACCOUNT FISHER HILL RESERVOIR

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and was 20 feet above its finished bottom, consequently the amount of earth excavation was more than usual in a reservoir of this capacity. In designing this reservoir, the capacity and elevation were assumed as fixed by the requirements of the case, and the different sites were judged by these standards. The elevation was established from the fact that this was to be the main reservoir to supply the two distributing reservoirs—one already built on Parker Hill, in which high water is at grade 219; and a second one which it is proposed to build at Roslindale at practically the same elevation. The bottom of Fisher Hill reservoir was fixed at grade 221 and high water at grade 241, so the latter can be completely emptied into the two distributing reservoirs, and when both reservoirs are full there is head enough to give a velocity of about 3.5 feet per second in a 30-inch pipe connecting the two reservoirs. If the reservoir had been built at a greater elevation the first cost would have been somewhat less by diminishing the amount of earth excavation; but every additional foot the water is lifted above the required elevation is a perpetual expense, and when the consumption amounts to 10,000,000 gallons per day, will more than equal 4 per cent. on the cost of the extra excavation.

The site of the reservoir was covered with black loam, averaging one foot in thickness, and with about the same amount of yellow loam, the subsoil being a compact, clayey gravel of excellent quality for reservoir embankments. The only exceptions were some veins of loose gravel and sand that ran diagonally across the reservoir.

One of these veins extended into the excavation for the gate chamber, and was completely cut off by that structure. The principal vein extended from near the southeast corner of the reservoir across the reservoir and through the western bank, and was about 25 feet in width.

An excavation carried 7 feet below grade failed to cut it off, the material apparently becoming coarser instead of disappearing. The concrete foot wall at that point was made of Portland cement, and extended to the depth of the extra excavation.

The embankment is 20 feet wide on top, with outside slopes of 2 horizontal to 1 vertical and inside slopes of 1¾ to 1.

The method of building the banks was as follows: After the location for the embankments had been stripped to the hard-pan, horizontal steps were cut on sloping ground and the material from the excavation was spread in 4-inch layers, wet by watering carts and thoroughly rolled with grooved rollers. All stones larger than 3 inches in diameter were picked out before rolling. Care was taken to keep the coarser material on the outside of the embankment. The inner slope was built one foot thicker than required, and afterward trimmed off to the proper line so as to insure solid work on the face, it not being practicable to roll the edge of the slope as thoroughly as the other portions. This rolling was very thoroughly done at a cost of 2¼c. per cubic yard, including water and use of plant.

The inner slope of the embankment is covered, to a line 2 feet above high water, with a layer of puddle 2 feet in thickness. This is made by mixing brick clay with selected material from the excavation in the proportion of one part clay and two parts of gravel, from which all stones larger than 1 inch in diameter were removed.

The puddle was generally mixed in large boxes located on the slope, above the points where the puddle was to be deposited.

At first an attempt was made to mix the puddle in pug-mills, but the operation was too slow and expensive, and also left the puddle in too moist a condition to be used in surfacing the slopes.

When mixed in boxes the clay was partially pulverized and spread in alternate layers with the gravel; each layer was soaked with water to soften the material.

After standing some time the material was cut down with shovels, mixed together, then shoveled into the slopes and rammed into pl ac with wooden rammers. The great tendency was to make the puddle too wet, so that it sometimes crawled on the slopes and in drying became full of sun cracks.

The amount of water used was regulated by the condition of the clay. If the clay was thoroughly pulverized before mixing but little water was necessary, but when mixed in a lumpy condition a thorough soaking was necessary to soften it sufficiently to be thoroughly mixed. The best results were obtained by spreading the clay over a smooth, hard surface and thoroughly pulverizing it with a grooved roller. This could only be done successfully in dry weather, when it could be easily reduced to a powder. Clay that was piled up over winter and exposed to the action of the frost was more easily worked.

After the puddle had become sufficiently hard the sun cracks were calked with a tool made from a piece of plank with a handle, and driven with large mallets. The surface was then trimmed to line and covered from the base to grade 235 with a layer of Portland-cement concrete 9 inches thick. This concrete was put on in sections, about 10 feet wide.

Planks, 9 inches in width, were laid on the slope at each end of a section, and the upper edges set exactly on a line with the finished face of the slope. Covering planks were spiked on to these rangers, one at a time, and the concrete rammed between the puddle and the planks, the planking being carried up just in advance of the concrete filling. When the section of concrete was partially set the planks were removed and the surface was troweled over and surfaced with mortar.

A space about six inches wide was left between the sections so the ranger planks could be removed. These spaces were allowed to remain unfilled for some time, so that any settlement in the puddle would be less liable to crack the concrete. Two-inch wrought-iron pipes were built into the top and bottom of these gaps to drain the back of the concrete when the water in the reservoir may be drawn down.

The slope above the concrete to grade 243, or two feet above high water, is covered with paving of an average thickness of 15 inches, which is laid dry on a bed of broken stone generally 12 inches thick, but two feet thicker on the upper portion.

The paving stone came from ledges in Brookline and Roxbury, with the exception of the top course, which is granite.

The concrete on the slopes was not laid within six feet of high water line, and is thus protected from injury by frost in any ordinary condition of storage in the reservoir.

The concrete makes a clean, neat finish for the slopes, and the section of

the reservoir can be finished exactly to the neat lines, so its capacity can be accurately figured. It is also cheaper than paving on a stone ballast. Using the prices paid on this contract, the saving was 43 cents per square yard. Using the estimated prices, the saving would be 70 cents per square yard.

To prevent any slipping of the puddle and paving on the slopes, an abutment of American cement concrete was placed at the foot of the slope.

The bottom of the reservoir is covered with puddle 2 feet in thickness, made from brick clay and selected material from the excavation, generally in the proportion of one part clay and five parts gravel. This puddle was mixed in place as follows: A layer of gravel was spread, the large lumps broken, stones picked out, and was pulverized with a disk harrow; a thin layer of clay was then added and treated in the same manner; the layers were wet by a watering cart, and a second layer of gravel was spread. After the top layer had been harrowed and mixed with the preceding layer, and had been sufficiently moistened, the combined layer was thoroughly rolled with grooved rollers. The thickness of the two layers of gravel and one of clay, when combined, was 4 inches. The proportion of clay was regulated somewhat by the character of the bottom and by the quality of the gravel put into the puddle, but was generally as above stated.

Puddle can be made in this way at a very small cost if the material can be used directly from the excavation without rehandling. The actual cost, as figured from the force account, was 34 cents. The slope puddle cost the contractors 71 cents per cubic yard.

A strip of Portland cement concrete, 10 feet wide and 6 inches thick, was laid along the foot of the slope. A gutter of the same material is built in the centre of the reservoir, and extends into the gate chamber to drain off the bottom of the reservoir.

The inner slope above the paving, the top of the embankment, with the exception of the gravel walk and the outside slopes, are covered with 2 feet of loam. A berme extends nearly around the outer slope of the the embankment. This berme is 12 feet wide and its top surface is 7 feet below the top of the embankment. This berme was not on the original plan when the work began, but it made a convenient way of disposing of the surplus material, and it is also a convenience in caring for the slopes. The material was not spread in layers or rolled, it not being considered a part of the embankment proper.

The cross sections were taken every 25 feet upon the site for the reservoir and the sections were plotted on cross-section sheets on a scale of 50 feet horizontal and 10 feet vertical. In making the monthly estimates, the heights taken on the excavation were plotted on the same sheets and the amount of the excavation was obtained by means of a planimeter. The leveling was done by the method described by Mr. F. P. Stearnes before this society in 1885. The level was set at some fixed grade and the heights were read from a 15-foot rod that was graduated to read from the top downward. The level being set at a grade of some whole foot, whose last figure was 5, it follows that if the reading on the 15-foot rod was 0, the height at that point must be some even foot whose last figure is zero, and whatever the reading is on the rod, it must be added to the latter grade.

For example, if the instrument was set up at grade 245, a reading of zero on the rod would be equivalent to grade 230, a reading of 1.20 on the rod would mean grade 231.20, etc.

Of course the level could be set at any elevation, and the readings on the same rod would be added to a grade 15 feet less than the height of the instrument, but it simplifies the matter very much to use the first method.

The cross-section sheets can be taken on to the ground and the heights plotted as fast as they can be read. The only drawback to this method at Fisher Hill was that estimate days were notoriously rainy or windy. When one is employed on a work of this character he becomes so familiar with the elevations of the different points that it is a very simple matter to set up a level at the desired grade.

Steel ploughs, drawn by four horses abreast, were used to loosen the material in the earth excavation. Two, and sometimes three of these ploughs were used, and the engineers were fortunate when they did not have to cross-section the whole location for the monthly estimates. For this reason the method just described was unusually advantageous.

The gate chamber is located at the centre of the eastern embankment. It feet is 20 × 20 feet 10 inches inside dimensions, with side walls of granite masonry. These walls are 26 feet high, 5 feet 6 inches thick at the bottom, and 3 feet 6 inches at the top. A concrete foundation 2 feet thick extends under the whole chamber, and below this foundation are three cut-off walls of concrete 2 feet thick and 2 feet wide, which extend across and under the foundation, parallel with the center line of the embankment.

There are two rubble buttress walls on each side of the chamber extending into the embankment. The sides and front of the chamber are surrounded by a puddle wall 2 feet thick.

The chamber is divided by brick walls into effluent and influent chambers.

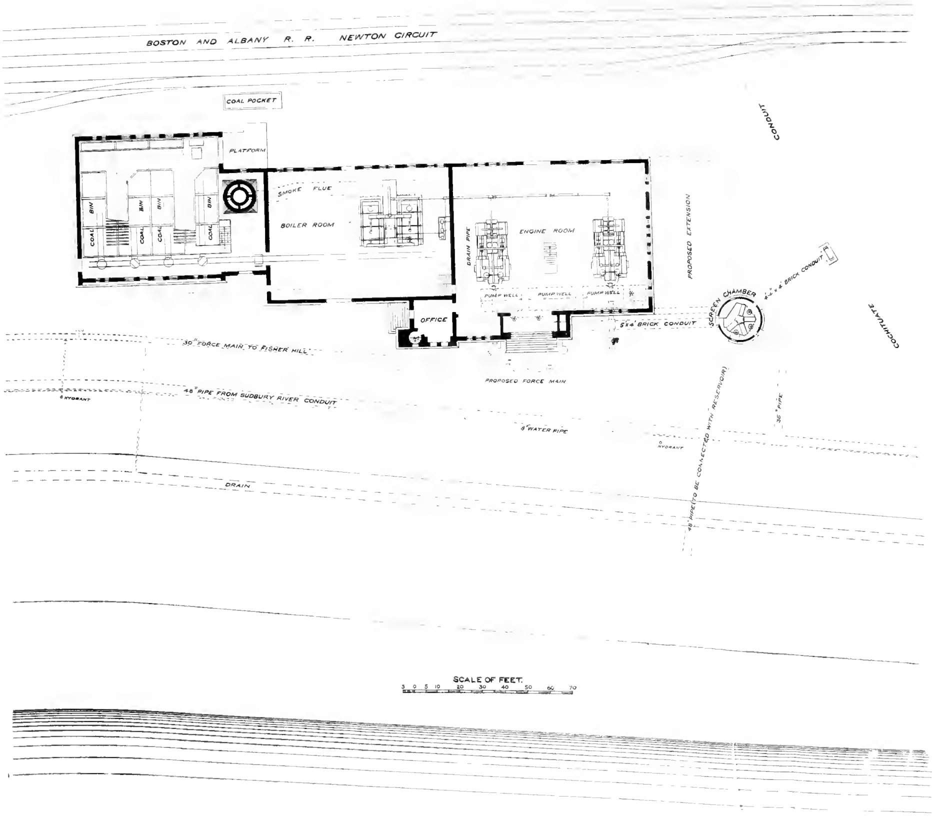
There are two 30-inch × 30-inch iron sluice gates, one near the reservoir end of the influent chamber and one in the division wall between the two chambers: two 36-inch × 36-inch gates are placed at different elevations near the reservoir end of the effluent chamber, and there is one 16-inch × 16-inch waste gate.

By closing the gates in the influent chamber the water entering the reservoir can be made to pass over a weir, by which the water delivered by the pumps can be measured. The sides of the influent chamber in front of the weir are faced with brick to present a smooth surface to the water approaching the weir. At the official test of the pumping machinery in August and September, 1888, the sides of the approach were faced with planed white pine to make as smooth a surface as possible.

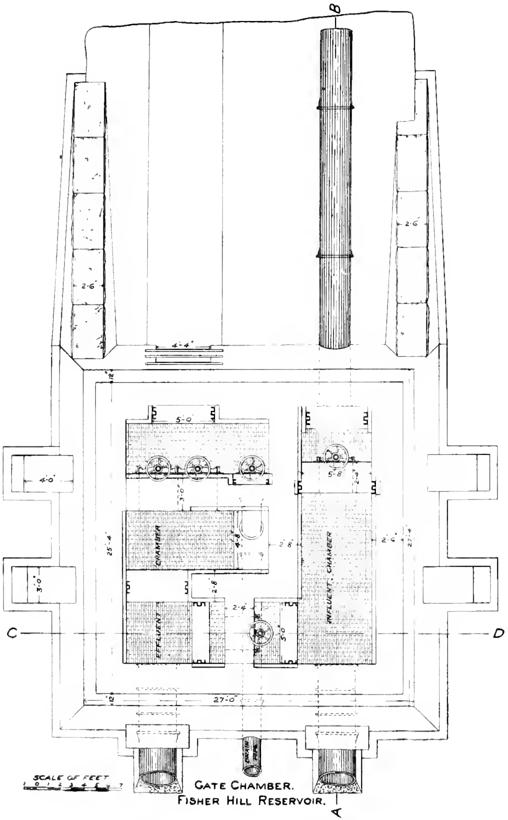
When the weir is in operation there is a depth of over 20 feet in front of it and the channel is 5 feet 8 inches wide, so the velocity of approach is practically removed.

A convenient dry chamber for the hook gauge can be made between the gate and the stop planks in the cross-connection chamber.

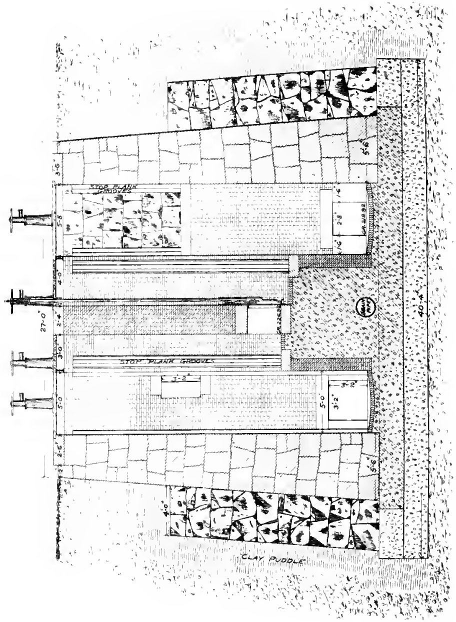
The water enters the gate chamber from the force main, and is conducted from thence to the centre of the reservoir through a line of 36-inch pipe, where it is discharged upon an apron of Portland cement concrete.



HIGH SERVICE SYSTEM BOSTON WATER WORKS—CHESTNUT HILL PUMPING STATION



Gate Chamber.
Fisher Hill Reservoir.

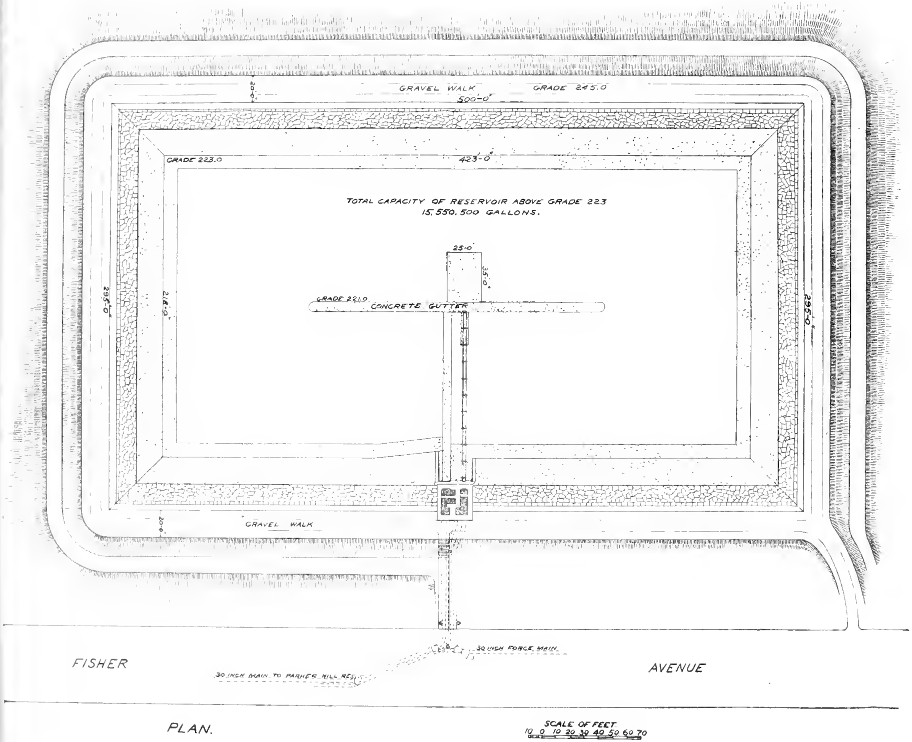


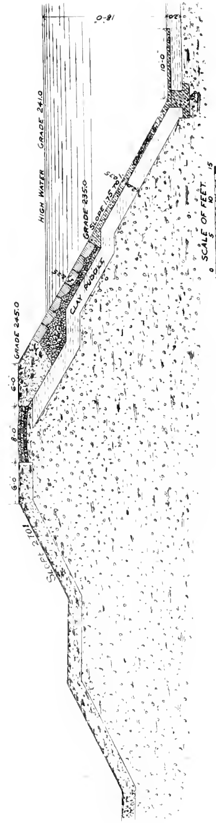
Gate Chamber.
Fisher Hill Reservoir.

Section on line C-D.

SCALE OF FEET

HIGH SERVICE SYSTEM, BOSTON WATER WORKS.





Section of Embankment.

HIGH SERVICE SYSTEM BOSTON WATER-WORKS—FISHER HILL RESERVOIR

The last three lengths of the pipe are deflected vertically, to direct the current upward and prevent the scouring of the reservoir.

The water leaves the effluent chamber through a 36-inch pipe, reducing to 30 inches after passing beyond the embankment, and continues a distance of 6,800 feet to the corner of Prince and Perkins streets, where a branch is located to be extended to the proposed reservoir at Roslindale.

The 30-inch pipe is reduced to 24 inches beyond this branch, and is laid to Parker Hill reservoir, a distance of 8,000 feet.

A force account of the work on the reservoir accompanies this description. From these figures it appears that 1.43 barrels of cement were used per cubic yard of American cement concrete, 1.54 barrels of Portland cement per cubic yard of concrete, and 1.13 barrels of American cement per cubic yard of brick masonry. These amounts are about 1 [illegible] of a barrel more than shown at the pumping station.

In the rubble masonry rectangular granite blocks were used, and laid with close joints, so that only $\frac{58}{100}$ of a barrel of cement per cubic yard was used.

WEST ROXBURY HIGH-SERVICE.

The highest lands within the limits of the city is Bellevue Hill, in West Roxbury, whose summit is 331 feet above water-works base, or 90 feet above high water in Fisher Hill reservoir. There are about 100 acres of land above grade 200, and 1,500 acres above grade 170.

The population of these elevated districts will always be comparatively small, and it would not be advisable to pump the whole of the water used in the high service to a height adequate to supply these extremely high points. The alternative was to build a separate system on a small scale. The plan adopted was designed to supply the territory above grade 170. This was accomplished in 1886 by building a small pumping station at the corner of Washington street and Metropolitan avenue, in Roslindale, containing two Knowles' pumps, each with a capacity of 400,000 gallons per 24 hours, and two upright boilers, 42 inches in diameter and containing 85 2-inch tubes six feet long. A 12-inch force main, 4,000 feet long, connects the pumps with a wrought-iron tank 24 feet in diameter and 40 feet high, located on the summit of Bellevue Hill.

This tank holds 125,000 gallons when filled to within three feet of the top.

The tank is located on a lot of land that was given to the city of Boston for park purposes, and as it is the highest land within the limits of the city, an unusually fine view is presented on all sides. An observatory tower has been built over the tank, which prevents all trouble from ice in the tank, and at the same time is a very appropriate structure for the locality.

The height of water in the stand-pipe is shown at the pumping station by a mercury gauge. An independent lead pipe was laid in the trench with the force main and connects the gauge with the standpipe.

The description of the high-service works of the Boston Water-Works would not be complete without mentioning those at East Boston, which are independent of the main works.

The first works were built in 1880 to increase the supply on two hills in East Boston which at that time were but poorly supplied from the low ser-

vice. A small wooden pumping station was built on the reservoir lot on Brooks street, and water was pumped from the low-service main against a check valve with a by-pass, placed in the pipe between the pump and the reservoir.

By weighting the lever arm of the by-pass the pressure in the distributing pipes can be regulated at pleasure, the surplus water entering the reservoir and furnishing the supply at a diminished head when the pumps are stopped

The pumping plant consisted of two Worthington pumps, each of a capacity of about three-quarter million gallons per day, the steam being furnished by two upright boilers 42 inches in diameter.

Breed's Island, a portion of East Boston has never been supplied with water. Its elevation is too great to be reached by the low-service works, and as there were only a few houses on the summit, nothing was done about furnishing an independent supply until 1888, and the works are now nearly completed. There are about 100 acres on this hill above grade 50, and its summit is at grade 155.

A new station, built of brick, is located on Condor street at the foot of Brooks street. This is to supersede the small station on the reservoir lot, and will also contain the pump to supply Breed's Hill.

A 12-inch force main 11,000 feet long is laid from the station to a stand-pipe on the summit of Breed's Hill. This stand-pipe is the same size and similar to the one at Bellevue Hill.

The piping at the station is so arranged that either one or all of the three pumps can supply the new stand-pipe or the old reservoir in Brooks street.

Steam is furnished by two upright tubular boilers 48 inches in diameter and each containing 340 square feet of heating surface.

The height of water in the stand-pipe is indicated and registered at the pumping station by one of Winslow's electric gauges.

The height of water in the reservoir is shown by a mercury gauge connected directly with the reservoir by a half-inch lead pipe.

FOUNDATIONS OF THE LIMFJORD BRIDGE.

By O. Sonne, Member of the Engineers' Club of Kansas City.

[Read May 6, 1889.]

The Limfjord bridge was built for the Danish State Railroads as early as 1874–78, and therefore a description of the works on the foundations can hardly be expected to furnish much that is novel or worthy of imitation; but as many difficulties were encountered which would be called quite serious even at the present day, and as most of the piers reached to the greatest depth attained up to that time, a short account of the work, with its failures and triumphs, may not be without interest.

The bridge was built near Aalborg to connect the two parts of the trunk line, which runs near the eastern coast of the Danish peninsula and forms an important connecting link between Sweden and the European continent; besides it is the main artery of the peninsula itself. Before the completion of the bridge, the transfer of freight and passengers across the

Limfjord was effected by means of ferry-boats, with the inconvenience and loss of time always attached thereto, and with frequent blockades during the winter. The surveys and borings showed clearly that considerable time would be consumed and difficulties of a hitherto unknown character encountered in building a permanent bridge, but at the same time the advantages of a bridge were considered sufficient to counterbalance the probable cost, and the government decided to proceed. In order to take advantage of the experience gained in other countries on similar works, an international invitation was issued to compete for the prize which the government offered for the best design.

At the site selected for the bridge the bottom consists of soft mud, the upper part almost liquid, increasing in solidity downward. The lower parts consist of a mixture of mud, shells, organic matter and sand. Below this the original bottom of the fjord is found, at the northern shore at a depth of 53 feet below mean stage of water, sloping toward the south to a depth of 113 feet below mean water. It consists mainly of sand, with layers of clay of less magnitude. The sand is coarse on top, becoming gradually finer downward to a depth of 155 feet, at which point the borings were stopped. Very nearly the same features obtain for a long distance on both sides of the bridge site. The Limfjord at this place is about 2,700 feet wide, with shallow water next to the shores, leaving a channel 1,000 to 1,100 feet wide and 40 feet deep, which is not subject to material changes. The maximum velocity of the current is 7 feet per second, caused partly by the tide and partly by wind. The former is insignificant, the spring tide being only 16 inches, whereas the wind causes changes in the stage of water from 5 feet above to 2½ feet below mean water. The ice, in exceptionally severe winters, reaches some 20 inches in thickness, ordinarily only 6 to 12 inches. When it breaks up with a current from the west its force is considerable, and has to be guarded against; while the ice coming from the east is rather insignificant, and, besides, a pontoon bridge, built east of the railway bridge, serves as an efficient ice-breaker.

Some of the requirements for the bridge were:

That its total length be 1,236 feet.

It should be provided with a draw with two openings, each of them 78 feet in the clear.

It should carry a single railroad track, and be so constructed as to serve as a highway bridge besides.

Top of rail should be 10 feet above mean water, and the superstructure leave at least 8 feet clear above mean water.

The superstructure for the railroad track should be designed to carry a live load of 1 ton per lineal foot; the live load for the road and sidewalks was fixed at 50 pounds per square foot.

The piers should be tested with a load equal to three times the weight they would ever be called on to sustain.

Out of thirty-three projects and bids which were received, one was chosen, presented by the French Bridge Company, Compagnie de Fives-Lille, proposing to sink circular stone piers, 19½ feet in diameter, by the pneumatic process, down to solid bottom, *i. e.*, 113 feet. If it should prove impracticable to sink them below 83 feet, which was the greatest

depth yet attained, it was proposed to put in screw-piles from the air-chamber, and in that way obtain a solid support. The superstructure was to consist of prismatic girders, with two fixed spans south of and four north of the draw, the track to be supported at the bottom of the girders and the highway to be on top, with separate approaches of iron. This project was somewhat modified: the total length of the bridge was reduced and the dimensions of the piers were enlarged: besides it was recommended, in case the piers should not reach solid bottom, to drive down hollow iron cylinders by means of compressed air, instead of using screw-piles. This expedient, however, was not required, as all the piers were successfully carried to a solid foundation. The superstructure, although designed to carry the additional weight of a highway, was only provided with a railroad track, the construction of the highway not being deemed urgent at the time.

As finally built the main bridge had the following spans, beginning from the north end: Two spans of 226.2 feet and 260.7 feet, covered with continuous girders; two spans 87.85 feet each, covered by the draw, and two spans 217.0 feet and 215.9 feet, covered by continuous girders. Numbering the piers from the north, Nos. 1 and 7 were made 14.6 feet and 32.8 feet over all, the cross-section rectangular with a semi-circle at each end. Piers Nos. 2, 3, 5 and 6 were 16.4 feet and 41.0 feet over all, the cross-section rectangular, with a semi-circle on the east end and a pointed cut-water on the west end. Pier No. 4, the pivot pier, tubular, 27.9 feet outside diameter, 11.5 feet inside, with a pointed cut-water on the west side, making the dimension in the direction of the current 36.9 feet. The piers were built without a batter, and the dimensions mentioned apply to the main body of the piers from the cutting edge of the caisson to 7.2 feet below mean water. At this height is an offset of about 18 inches, and from 2.6 feet above mean water to the top, piers are rectangular, with broken corners, except the pivot pier, which is circular.

When the bridge was nearly completed it was found desirable to add two short spans, one at each end of the bridge: the additional piers were built on land and supported by piles. Presenting nothing of special interest, they will not be included in the following general description of the piers.

With allowance for the difference in cross-section the piers were all of the same type. The caisson was built of iron after the common model, its shape and dimensions corresponding with those of the pier: the height inside varied from 7.9 feet to 8.9 feet, the sides were made of ½-inch plate iron, stiffened by horizontal angle iron and re-enforced at the cutting edge. On the inside of the walls triangular plate iron brackets were riveted to the side of the caisson 40 inches apart, extending from the cutting edge to the ceiling, and 3 feet wide at the top; these brackets supported riveted plate girders 20 inches high, to which the ceiling was riveted. One shaft 6½ inches in diameter went up through the pier; it was made in sections of 6½ feet and of ⅜-inch plate.

The sides of the caisson were extended upward with a thickness of $\frac{5}{32}$ inch, and the upper edge kept above the water to serve as a coffer-dam for the masonry, which was put in only fast enough to overcome the buoyancy and friction of the pier.

The main body of the piers was built of hard burned brick of excellent quality, protected by the iron coffer-dam up to the offset. 7 feet 2 inches below mean water: from here upward the outside of the pier and the copings were of granite, the interior of brick. The mortar used was made of Portland cement, mixed in the proportion of one of cement to two of sand.

The sinking of the piers was conducted from scaffolds, of which the ones used at piers No. 1 and 7 consisted of twenty-four 12-inch piles, 50 feet long, supporting a platform, while each of those used for the other piers consisted of six piles 40 inches in diameter 90 feet long, built up of eight pieces of timber well fastened together, as shown on the drawing: on the lower part the diameter was increased to 52 inches by a 6-inch planking.

It was first attempted to sink these piles by means of a Friedmann's pump, constructed on the same principle as a Gifford's injector. A current of water is forced through it under a pressure of about 100 pounds, and causes a suction through the pipe at the bottom. This pump was applied to the bottom of the piles, and it was intended that the suction should draw the mud up through an opening 15 inches square, left through the centre of the pile for that purpose, but although a system of rotating knives was added at the bottom of the piles to loosen the mud the plan did not succeed. The mud, though soft, was still too stiff and tenacious. After this unsuccessful experiment the piles were forced down by a direct application of weight. For this purpose a scaffold 40 feet high was built on two pontoons 35 feet × 11 feet × 3 feet 6 inches, connected by cross-girders, and far enough apart to leave room for the pile between them. The pontoons were anchored in the place where the pile was to be sunk, and after the pile had been raised between the pontoons and pulled down through the upper layers of mud with ropes and winches, the weight of the pontoons was brought to bear on it by means of rods that passed from the deck up through two cross timbers on top of the pile, where they were held by nuts and washers. By tightening the nuts as the pile went down, and by loading the pontoons, the weight applied was brought up to 165,000 pounds. In this way a penetration of about 40 feet was obtained, and six to eight men would sink one pile in two days.

After the piles were sunk a platform was built near the surface of the water, and here the caisson was put together. Resting on top of the piles were iron girders that served as support for four rods hooked around the cutting edge of the caisson and intended to keep the piers suspended till it reached solid bottom. Each rod was composed of links, and could be lengthened as the pier went down. It ended above in a screw 2⅝ inches in diameter, 8 feet long, and was held by nuts and washers on top of the iron girders. An iron strap was suspended on each side of the rod to hold the weight of the pier while the rod was lengthened. The drawing shows the arrangement. *A* and *B* are two adjoining links, their combined length 6 feet. In the position shown the piers can be lowered—by loosening the nuts above—until the upper end of *A* approaches the lower end of strap *E*, then a pin inserted at *d* transfers the weight to the strap, and two more links can be added between *A* and the screw, after which the pin at *d* is removed and the lowering of the pier resumed.

When the caisson was put together and suspended the platform was removed and the caisson lowered into the water, sections of the shaft and of the outside iron shell put in, and at the same time the masonry would be

started, first along the outside of the pier and around the shaft, while the main body of the masonry would be put in later as needed to overcome the buoyancy and friction of the pier. A space of a few inches was left open between the masonry and the shaft, in order to make it easier to remove the latter afterward.

The excavation was done at the beginning of the work with the above mentioned Friedmann's pump. However, it did not work satisfactorily on account of the consistency of the bottom, and after having been used for about six weeks it was definitely abandoned. After this the material was dug out with spades and shovels, filled into buckets and hoisted up into the air-lock, at the upper end of the shaft, and from there passed out into the open air. To accomplish this a box was inserted in one side of the air-lock, divided in two parts, each of which was made to open from the outside and inside. When filled with excavated material from the inside the box was closed, relieved of the air pressure and emptied from the outside, and by using the two compartments alternately the work proceeded without interruption.

Occasionally during the sinking of the piers the character of the material would permit the excavation to go on without compressed air, either when the material was so soft that a clam-shell dredge, working through the open shaft, could keep the pier going, as was the case on piers No. 3 and 4, that were sunk in this way to 85 feet below mean water, or when the bottom was so impervious to water that the air chamber would keep dry without air pressure. This advantage was had at several of the piers, only for a few feet, however.

The construction of the air-lock underwent considerable changes during the work. At first it consisted simply of a section of shaft, with trap-doors in the ceiling and floor, and with the above-mentioned box for passing out the excavated material, together with the gear for the elevator, which was run by compressed air. This arrangement was very soon found to be imperfect. The elevator had to stop every time the air-lock was closed, and especially when the pressure went up to about three atmospheres; the equalizing of pressure in going in an out occupied so much time, and the changes of crew took place with so short intervals, that a great deal of time was lost. To prevent this, two separate air-locks were riveted one on each side of a section of shaft 9 feet high, which contained the box for passing out material and the gear for the elevator. As this section of shaft was constantly in connection with the air chamber, the elevator could be run without interruption, and one set of men could go out while another went in. The elevator, which was at first run by compressed air, was changed to be turned by hand with cranks on the outside of the shaft, and afterward to be run by a steam engine standing on the top section of the shaft.

How much time was saved by the change in the air-lock may be judged from the circumstance that with comparatively low pressure the men worked four hours with eight hours' rest; with heavy pressure only three hours with nine hours' rest, and on account of the bad effect of the pressure on the men, and especially of gases arising from the bottom, the supply and escape cocks in the air-lock had been diminished from necessity to such an extent that with a pressure of three atmospheres it took 45

minutes to change the pressure in the air lock, and consequently at least one-fourth of the time would go to change the crews.

When the pier had been landed the air chambers were filled up with concrete, consisting of one part Portland cement to two parts of sand and four and a half broken stone, covered with a layer of cement mortar to keep out the water. The air pressure was diminished gradually, the shaft taken out and the well filled with concrete, and the masonry completed. Above the offset, 7.2 feet below mean water, a temporary coffer-dam of iron was used, while below the offset the iron sheathing was left in. On the pivot pier, which was built hollow, the well, $11\frac{1}{2}$ feet in diameter, was filled up with sand. After the completion of the piers a large amount of rip-rap was placed around them, with the view to afford them a better support sideways than could be obtained from the mud; a total of about 15,000 cubic yards was thrown in for this purpose.

A peculiar accident happened on pier No. 5 when it was nearly finished: the pier was landed and the air chamber filled with concrete. When it was attempted to remove the shaft, which had been an easy matter on the other piers, it was found impossible to move it, probably because the lower section was held by mortar, etc., that had been dropped between it and the masonry. It was then decided to disconnect at the next higher joint, and as some water had seeped through the concrete, the pressure was let on, and three men went down to loosen some of the bolts. They remained below for three hours, and had just given the signal to diminish the pressure, when suddenly the shaft, 98 feet long, was thrown out of the pier with so much force that the lower end went some 30 feet above the top of the pier. It turned over and fell into the water, knocking a hole in the coffer-dam, so that the pier filled with water. The three men were killed: one of them went up with the shaft, the two others perished in the pier. The pier was not damaged seriously. The coffer-dam was easily repaired, only the water on rushing in carried some material down into the well, which was removed with a clam-shell dredge, except about six feet of pure sand that was allowed to remain in the pier. The cause of the accident was probably that the laborers removed too many bolts before giving the signal to diminish the pressure, which was 35 pounds, so that it tore out the remaining bolts and ejected the shaft. An examination proved that no explosion could have occurred, while the calculated height to which the compressed air could throw the shaft agreed very well with the observed height.

Another accident occurred, this time at pier No. 2, carrying with it no loss of life, but otherwise in its consequences of vastly greater significance than the one just mentioned. The pier had been lowered to about 52 feet below mean water, when, during a heavy gale, the barge that carried the air-compressors, steam engines, etc., sprung a leak and upset. The boilers were lost, but the machinery was recovered. The work had already been suspended on account of the storm, and probably for this reason no life was lost, but the loss of the boilers contributed to a great extent toward the subsequent accident, the complete overturning of the pier. As no other serviceable boilers were on hand the air-compressors could not be worked, and, in order to lose as little time as possible, the work on the masonry was continued and the pier allowed to sink without any excava-

tion being done. The pier was still suspended in the four rods, but in the absence of air-pressure to lighten the pier, and with no possibility of regulating the sinking from below, the only means to keep the pier in equilibrium was to counteract an initial leaning by adding masonry on the opposite side. This worked very well, however, until the cutting edge was 62 feet below mean water. At this point the pier began to lean over north, and got out 13 inches from the vertical position. By adding masonry on the south side it was straightened again, but began immediately to lean over south, and this movement continued in spite of all efforts to check it. Masonry and loose stone were piled up on the north side and jacks applied between the scaffold piles and the pier, to no avail. The pier turned over completely and took the scaffold with it. The cutting edge had at this moment reached to 69¾ feet below mean water, and the masonry was carried up to one foot above the water. The pier turned over on the centre line of the bridge and moved a little toward the north: it turned, as it were, on a pivot 16 feet above the cutting edge. The most plausible explanation of the occurrence, which was also afterward confirmed, was that the pier struck a thin layer of comparatively hard material sloping toward the north. On reaching it the pier would naturally lean over north, and after it had been straightened and lowered further the north side rested on the hard layer, while the south side had pressed through it, and the tendency of the pier to lean was thus reversed; while, moreover, the excess of masonry on the south side, instead of counteracting the tendency, would further it. Afterward, when a new pier was sunk, a layer of this kind was actually found.

Now a serious question arose as to whether it should be attempted to sink a new pier in the same place as the old one, or build a double pier straddling it. The third alternative, viz., to change the lengths of the two adjoining spans, so as to get away from the old pier entirely, lying as it was on the centre line of the bridge, was rejected at once, as it would require too much alteration in the superstructure.

The first alternative would afford the most satisfactory solution, but would involve the piercing, at a depth of 60 feet, of the masonry of the old pier, lined on the inside and outside with iron: and, even if it was possible to carry the new pier down to full depth afterward without getting it wedged in between the two pieces of the old pier or pushed out to one side, it was evident that the work was attended with great risks, and that it might result in a failure. On the other hand, the second alternative would be about as expensive as to build two complete piers, and would require an expensive iron structure to support the girders, besides ruining or at least badly interfering with, the symmetry of the bridge. It was feared that any blasting for the purpose of destroying the old pier might injure the other piers, and no attempts were made. After weighing all circumstances, the contractors finally took courage and decided to sink the new pier in the same place as the old one.

The overturning of the first pier occurred on Aug. 8, 1876, and the scaffold for the new pier was not commenced till the spring of 1877. On July 5, 1877, the new caisson was put together and the sinking commenced. When a depth of 40 feet had been reached, the contractors became aware that it would be necessary to move the pier; if not, it would strike the old caisson, and to break through that would be to undertake

too much. They were allowed to move it 10 feet 4 inches south, the length of a panel, and this was accomplished slowly, but successfully, by jacking over the iron girders in which the pier was suspended, while at the same time air pressure was applied to lighten the pier. On Aug. 25, 1877, the cutting edge reached the overturned pier at a depth of about 43 feet, and great caution had to be used to prevent the pier from sliding on the inclined surface. The iron and masonry was cut with chisels as far outside of the cutting edge as it was possible to reach, in order to prevent the wedging in of the new pier. It was slow work, and especially the cutting up of the shaft presented many difficulties. When the new pier reached through the masonry with the south side, it got an increasing tendency to lean over north; but a bracing against the superstructure, which had by that time been rolled out from the shore to midway between piers No. 1 and 2, set it straight again. At a depth of 65 feet some large pieces of iron were unexpectedly encountered, which proved to be the entire southern wall of the old caisson, with the brackets attached, but without any parts of the ceiling, which probably, together with the north side of the caisson, remained in place. This was another obstruction, and not till April 4, 1878, were the last pieces of the old pier removed, seven and a half months after the pier was reached, during which time forty men had been at work night and day. In all were removed 45,000 pounds of iron, 366 cubic yards of masonry, and 175 cubic feet of lumber belonging to the scaffold. During the remainder of the lowering some friction was noticed, caused by the old pier, but the sinking was completed successfully Aug. 11, 1878, and, strange to say, this pier is the only one in the bridge that is perfectly vertical.

In conclusion, the following list gives the time consumed in building each pier, as far as known, and the depth to which it was carried. The piers are named in the order in which they were built:

Pier No. 7.—Sinking commenced September 23, 1874; the pier finished September 17, 1875; time, 12 months, with some interruptions; depth 113.5 feet.

Pier No. 1—Sinking commenced April 1, 1875; the pier finished to above the water June 5, 1875; time, 9 weeks; depth 59.0 feet.

Pier No. 6.—Sinking commenced June 19, 1875; the pier finished July 27, 1876: time, 13 months, covering 5 months' suspension of work during the winter; depth, 112.9 feet.

Pier No. 5.—Sinking commenced September 21, 1875; the pier finished February 25, 1877: time, 17 months, with several interruptions; depth 112.9 feet.

Pier No. 2.—Sinking commenced June 10, 1876; overturned August 8, 1876: sinking of new pier commenced, July 5, 1877: the pier finished August 11, 1878: time, 13 months; depth, 111.9 feet.

Pier No. 3.—Sinking commenced September 7, 1876: the pier finished, September, 1877: time, 12 months: depth, 111.7 feet.

Pier No. 4—Pivot Pier.—The last 26 feet sunk in 9 weeks: depth, 111.55 feet.

The work was carried on under the direction of Mr. Tegner, Chief Engineer for the State Railways; Mr. Simons, Resident Engineer. The engineers for Compagnie de Fives-Lille were Mr. Pinguet, died at Aalborg in 1875, and Mr. Audebert.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

MONTANA SOCIETY OF CIVIL ENGINEERS.

July 20th, 1889.—The regular monthly meeting of the Society was held at the office of Mr. Beckler, Chief Engineer Montana Central Railway, at 8 P. M. President B. H. Greene in the chair. There were present Messrs. Sizer, Wheeler, F. J. Smith, Foss, Danse, de Lacy and Keerl.

The minutes of last meeting were amended and approved.

Col. W. W. de Lacy, chairman of the Committee on Irrigation, submitted a progress report, which was made the basis of a general discussion upon the irrigation question. The report was received and ordered filed. It stated that the committee had distributed about 1,000 circulars and township blanks, and had received reports from several sections of the Territory and were promised others. Col. de Lacy named the 25th inst., at 7:30 P. M., and the Surveyor-General's office, the time and place for the next meeting of the Committee.

A communication was received and read from Mr. A. B. Knight, of Butte, relative to the irrigation question He suggested that this "society anticipate the probable demand for legislative action and professional services in Montana by formulating legislation and by the consideration and discussion of the principles involved and the problems presented." Mr. Knight expressed himself as being in favor of State control of all irrigation works. He also called attention to the necessity of providing through proper legislation for the inspection of highways and bridges. These features were discussed by the meeting at considerable length, and the opinion prevailed that the interests of the State demanded that she should be assured the best possible results in her public works, and that this could alone be secured through enactments which would place in the hands of a competent engineer the direction of all engineering works of a public character. The discussion resulted in the unanimous adoption of the following motion: "That Mr. Knight's letter be received and filed and referred to a committee of five to be appointed to memorialize the Constitutional Convention, in the name of the society, on irrigation, highways and bridges, and that committee have full power to act." The chair appointed as such committee Messrs. F. L. Sizer, A. B. Knight, L. O. Danse, W. W. de Lacy and Geo. O. Foss.*

A communication was read from Mr. Geo. H. Robinson stating that on account of the demands upon his time he could not see his way clear to give the business of the committees, upon which he had been appointed, that care and attention its importance demands, and tendering his resignation as Chairman of the Committee on the Boiler Inspection Bill and as a member of the Committee on Library. He expressed his views upon the questions to be reported upon by these committees. On Library, he called the attention of the Society to the importance of securing at once, by purchase, the proceedings of the American Institute of Mining Engineers, from the origin of this institution to the present time, and suggested that the society become a regular subscriber for these proceedings. He stated that they

would soon be out of print; that there were now only eight sets in the Secretary's hands for sale, and considering the valuable matter they contained, they ought to have a place in our library. He suggested "that a special assessment be made of $5 per capita upon all members for library purposes, such assessment to be made payable with the regular annual dues, the funds to be expended under the direction of the Library Committee, and that each Member of the Society be requested to suggest the titles and descriptions of desirable works, and that a record be kept by said committee of such recommendations for future reference."

Upon the question of papers, he suggested "that in order to draw out criticism and argument from non-resident Members, that all papers considered of sufficient importance by the Society, or a standing committee for that purpose, shall be printed, and a copy sent to each Member, with the request that he submit a paper to be read on the subject, either in criticism or as an original discussion, and that a permanent committee be appointed for the examination of all papers for publication. I think this method would engender and foster the argumentative powers of our members. This is the only way I know of that we can advance our position as a Society. That each paper be submitted at least one month before a meeting to said committee for examination, and if they think it worthy, have it printed and a copy forwarded to each Member, allowing them ample time for preparing papers for discussion at the next regular meeting."

He suggested that the Society employ a stenographer to report its meetings, as it would greatly improve the members as extemporaneous speakers. "The stenographer to write up the proceedings, and give each member a chance to correct his own discussion, if he desires; otherwise it is to appear in our proceedings verbatim."

Mr. Robinson's letter was discussed and ordered filed, and referred to the Committee on Library. His resignations were accepted, and Mr. F. L. Sizer was appointed to fill the vacancy upon the Committee on the Boiler Inspection Bill, and Mr. Harry V. Wheeler to fill the vacancy upon the Committee on Library.

The Secretary reported having received for the library two bound volumes of the "Transactions of the American Society of Civil Engineers" for the year 1888; also "Preliminary Report on the Use of Metal Track on Railways as a Substitute for Wooden Ties, Bulletin No. 3, Forestry Division, Department of Agriculture."

[*Adjourned.*] J. S. KEERL, Secretary.

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*This committee met the 23d inst., at 7.30 P. M., at the Surveyor-General's office, and prepared a memorial, which was submitted as follows to the Constitutional Convention:

To the Hon. Members of the Constitutional Convention, Helena, Montana:

The "Montana Society of Civil Engineers" would respectfully represent to your honorable body that the subject of irrigation is now assuming the greatest importance to all the people of Montana—that in the near future there will be constructed large and extensive reservoirs, irrigating canals and other hydraulic works of great magnitude, requiring a large amount of engineering skill and experience, and that the lack of competent professional advice may lead to great loss of capital and life, as has been demonstrated in this Territory in the past and more recently in the terrible disaster at Johnstown, Pa., and the requisite safety can only be obtained through the inspection of the plans for such works—and the works themselves—by a competent engineer.

That in other States, particularly in California and Colorado, the office of State Engineer has been created, and the incumbent charged with the inspection and supervision of such works.

We therefore would respectfully recommend to your honorable body that a provision be incorporated in the Constitution of the State of Montana creating the office of State Engineer, to be appointed by the Governor, by and with the consent of the State Senate.

We would respectfully suggest that among his duties one of the most important should be the examination of the plans of all proposed reservoir-dams and the

periodical inspection of all dams and reservoirs within the limits of the State, in such manner as may be provided.

We would moreover respectfully recommend that in case the office is created, the State Engineer should be ex-officio a member of the Commission in charge of the State lands.

And your petitioners will ever pray, etc.

B. H. GREENE,
Pres't Montana Soc'y Civil Eng's.

J. S. KEERL, Secretary.
HELENA, Montana, July 24, 1889.

ASSOCIATION OF ENGINEERING SOCIETIES.
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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

CLEARING WATER BY SETTLEMENT—OBSERVATIONS AND THEORY.

BY JAMES A. SEDDON, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read May 15, 1889.]

There is much need of some definite knowledge of how water clears, or what are the laws under which the sediment in suspension in it passes out.

As far as the water-works engineer is concerned, the problem of simple settlement is confined to the consideration of a mixture of small particles of greater specific gravity than water, and of different sizes, which are at the commencement of settlement about uniformly distributed through the water, and which gradually settle out of it. That there must be some law or laws by which they settle out would hardly be questioned; yet, while any number of theories have been presented, I do not know of an effort that has been made public to substantiate or value any of them by a careful system of experiment and observation.

With the theories that have been advanced it is an open question whether settling basins should be shallow or deep, open or covered, what is the economic number in a given system, and even whether the settlement should be accomplished by a system of filling and drawing in rotation, or by a system of constant flow through the basins, water-works under each system being at present in process of construction, with the chances of making standing blunders on a large scale.

The experiments and observations that I have to present were undertaken as a preliminary to the design of the settling basins for the St. Louis water-works extension.

An effort was first made to reduce the range in size of sediment that is found in the average water, and to observe, in the hope of suggestions, the settlement in its simpler form, with particles not greatly differing in size. This was done as follows: A gallon jar of muddy water was allowed to stand five minutes and the water then siphoned off down to the sediment that had settled, the jar filled up with filtered water, shaken and allowed to again stand five minutes, the operation being repeated until the sediment left was of a kind that, when it was shaken up and allowed

to stand, it would leave the water very nearly clear at the end of five minutes. Having separated the five-minute sediment from the finer grades, the rest was concentrated into a gallon jar and the ten-minute sediment taken out in the same manner: that is, the jar was now allowed to stand ten minutes, and the sediment settling in that time washed with filtered water until it was clear of finer grades. After this the 20-minute, 1-hour, 4-hour and 24-hour grades were taken out in order.

These grades examined under the microscope showed a very fair graduation in order of size, much as a sample of river sand would show if sorted by sifting through sieves of increasing degrees of fineness. In fact, the generalization followed, that where the grades of the sand bar ended—that is, material rolled along the bottom or carried in intermittent suspension—the grades of the sediment, or material carried in permanent suspension, began, forming an unbroken scale of increasing degrees of fineness.

The fact that a separation of the sediment could be made in this way was taken as a sufficient basis for the provisional theory that, in the main, settlement was simply due to the action of gravity on the range in size of sediment, producing a corresponding range in the velocity of subsidence, with which velocity the respective grades passed down. The repeated washings with filtered water necessary to clear the finer grades from a given class was considered due to the finer grades reaching the bottom with that class from respectively lower and lower levels.

It was reasoned that if settlement followed this theory, there would necessarily be formed a curve of clearing from the top, the shape of the curve depending on the range and relative amount of the different grades in the water, and that this curve would pass down to the bottom through a definite phase. This curve could be clearly seen by the eye to pass down in the 5 and 10-minute classes, and while not so perceptible in the 20-minute and 1-hour classes, still during their settlement pipette samples taken from the top and bottom of the jar, when compared in test tubes, showed the top sample the clearer. It will be unnecessary to mention other experiments with the classified sediment.

The phenomena of settlement under this provisional theory may be discussed as follows. We may conclude that as an average the same thing is taking place in each vertical element, and so reduce the consideration to that of a single element of indefinite depth.

Taking A B as such an element and knowing that at the beginning of settlement the sediment is uniformly distributed through it, we may call the amount of it at any point, sediment density, or δ_1; thus the total sediment in A B at the beginning of settlement is represented by the area A B Y X. We may now arbitrarily take the sediment making up δ as arranged from A B in an increasing order of velocity of subsidence (approximately an increasing of size) and with this representation the theory assumes that the area A B Y X is made up of elements 1, 2, etc., which at the beginning of settlement start to move down with their respective velocities, as if they were solid strips; at the end of a unit of time, say one hour, the upper ends of the elements would have moved down to a curve, say A Z_1, and above Z_1 there would be respectively less and less amounts of sediment in the water as we approached the surface, the amount and grade being given at any depth by the ordinate of δ at that depth, to the

curve $A Z_1$. Or the amount of sediment $A X Z_1$ would have settled out of the water above Z_1, while at the same time an equal amount would have been deposited on the bottom. At the end of two hours the upper ends of the elements would have moved down to the curve $A Z_2$, where each

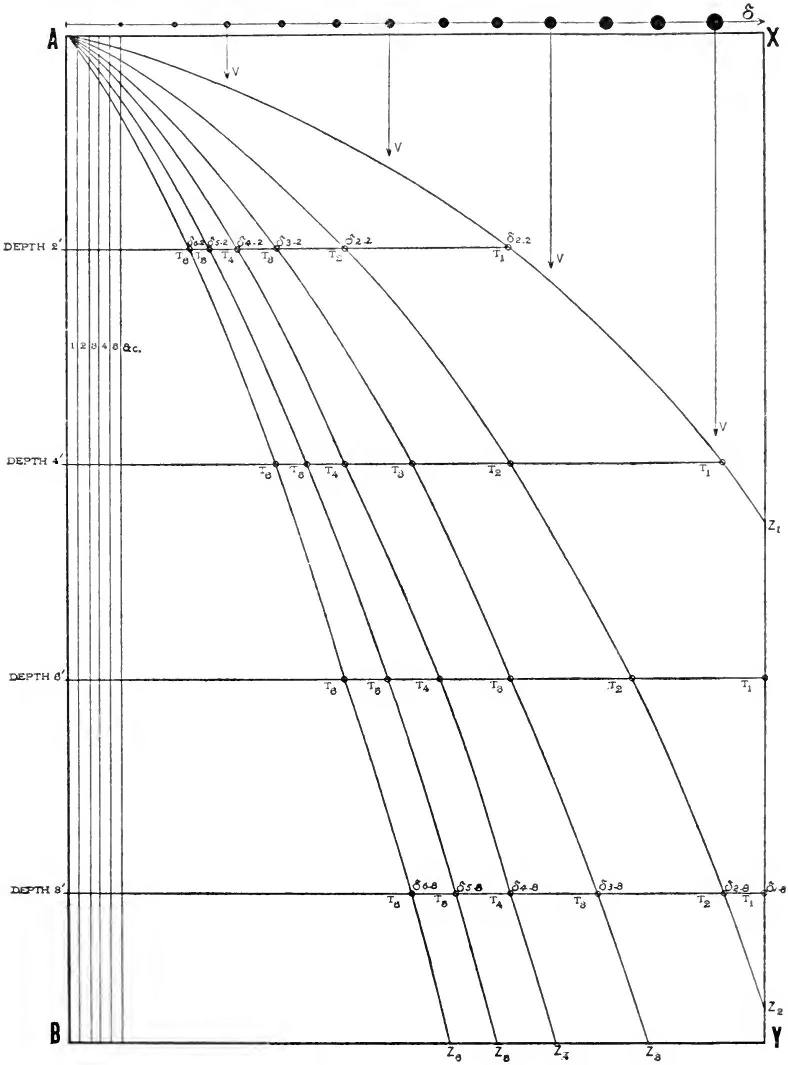


Fig. 1.

value of δ is at just twice the depth that it was in $A Z_1$; and so on for further hours.

It may be noted here that if this were the phenomena of settlement, in contrasting a settling basin of one depth with one twice as deep, the basin

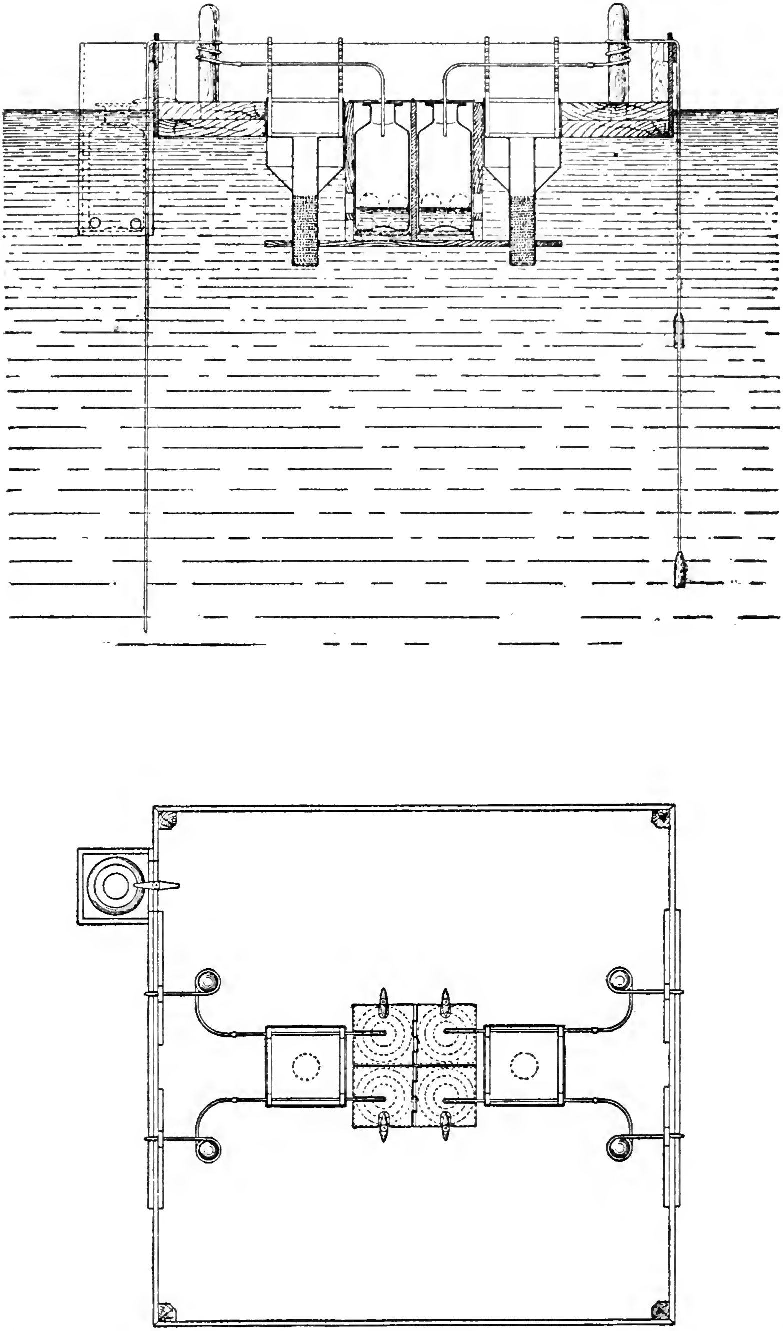
of double depth, though costing much more to build, would settle no more water per day, as far as simple settlement was concerned; for though it would hold twice the amount of water, it would take twice the time to bring this water to the same average clearness. So that at the outset a fundamental question as to the economic depth of settling basins rests on the determination of whether this theory of settlement is the true one.

In considering test observations; from the conclusion on this theory that the given elements making up the δ of the water move down as if they were solid strips, and that hence the same value of δ was to be found at a given depth in one hour, at twice the depth in two hours, etc., we see that the curve $A\ Z_1$, or the V, δ curve, should be determined from observations at any depth, for V would equal depth (d) divided by time of settlement (T). If, then, samples of water were taken at 2 feet and 8 feet depths, respectively, at stated times, T_1 T_2, etc., when the values of $V = \frac{d}{T}$, were plotted to the observed values δ of the samples, the points from the 2 and 8 feet depths should give one and the same curve. This would show that the velocity of subsidence of a given value of δ down to 2 feet depth was also the same velocity of that value of δ down to 8 feet depth, or that settlement was in accordance with the above theory. If, on the other hand, the observations at 8 feet depth gave a different curve from those at 2 feet, it would show that settlement was not in accord with this theory, and also give a measure of how far and in what direction the theory was in error.

With the above test in view, a series of observations on the settling basins were planned. As some prior observations that had been made on a number of samples suggested that a single sample taken from one place in the basin was a very imperfect measure of the basin as a whole, attention was first directed to a method of securing a sample that could be relied on. For this purpose an apparatus called a "Four-depth integrator" was planned. With the accompanying drawing it will be sufficient to say that its principle was that of a siphon drawing a small, uniform stream through a rubber tube adjusted to a given depth, and weighted to stay at that depth. The floats carrying the siphons were free from the float carrying the bottles receiving the samples, in order that the siphons might have a uniform head as the sample bottles were filled.

At the beginning of taking a series of samples the siphons were started in the side bottles and the float run out and back over a portion of its path, so as to clear the tubes of water in them, and get a distribution of water as it then was at the respective levels. The siphons were then changed to their respective bottles and the float moved slowly up and down the basin for taking the samples. The rubber tubes were respectively adjusted to 2, 4, 6 and 8 feet depth, and the series gave a simultaneous integration of the basin on these four planes, or observations in the above vertical element $A\ B$, with the assurance that they represented the average element.

The series were given numbers in order of taking, and the four samples of a series indicated by sub-numbers 1, 2, 3, 4 corresponding to 2, 4, 6 and 8 feet depth respectively. The average period of making an integration was about 20 minutes, and the mean time was taken as the time of the



Four Depth Integrator.

St. Louis Water-Works, Low Service Extension.

samples; continuous observations on the velocity of the wind were also made from the time that the basin was filled through the period of taking samples.

The element δ, or density of sediment in the sample, was measured in two ways. First, a liter of the sample was filtered and the weight of sediment in it determined, giving sediment by weight in parts per 1,000 as a measure of δ. To make this determination with a precision sufficient to approximate the small differences in weight between two series of samples, or between the different samples of the same series, required a very careful investigation into the absorption of moisture by the filter papers, and a process of correcting for the difference of moisture at different times by the observed difference of moisture in standard papers. This cannot be considered here further than to state that in this way weight in parts per 1,000 was made a moderately fair measure of the small changes of sediment taking place. The subject in itself forms the material of a paper which has in part been presented to the St. Louis Academy of Science. Second, a measure of δ was made, called a "Photo-comparator reading." The plate herewith shows the apparatus and method of making this measure. The principle is seen to be that of the Bunsen photometer, the point of equal light being read, first, with the lights clear; second, with a given thickness of the water sample placed in front of the stronger light. The difference of the readings giving a measure of the light intercepted by the water sample, or the muddiness of the water. This, so far as I know, is a new and very delicate measure of δ, and has the advantage of being rapidly made.

The drawing shows the apparatus as finally constructed, where two standard sperm candles were used simply to standardize the weaker light, and the stronger light was set from this to the zero of the scale. The readings of the observations that will be presented were made with a preliminary apparatus, in which the two sperm candles were used in the place of the weaker light, and the scale was shorter. A complete discussion of this, with theory of length of scale, strength of lights, and probable error of the observation, would, like weight of sediment, make the material for a separate paper.

After some preliminary experiment with the apparatus, complete observations were made three times on the settlement of a basin, Nov. 12–13, Nov. 14-15 and Nov. 16-17, all in a period of quite muddy and slowly clearing water. In each of these sets of observations series of integral samples were taken at intervals, designed to cover moderate changes in the clearing, through the period of settlement, and the element δ or density of sediment in the sample was measured, which, with continuous wind observations, formed the data of a set.

A general time variation of the data of all three sets is shown on plate I. The mean δ of the four samples of each series is there plotted to the time after filling when the series was taken, giving the average clearing of the basin from series to series, with the respective variations of the wind. These observations on the wind differ very much from the signal-service observations on the Custom House dome; but a considerable difference would be expected between the wind there and the wind on the basin wall, where these observations were made; and though simply

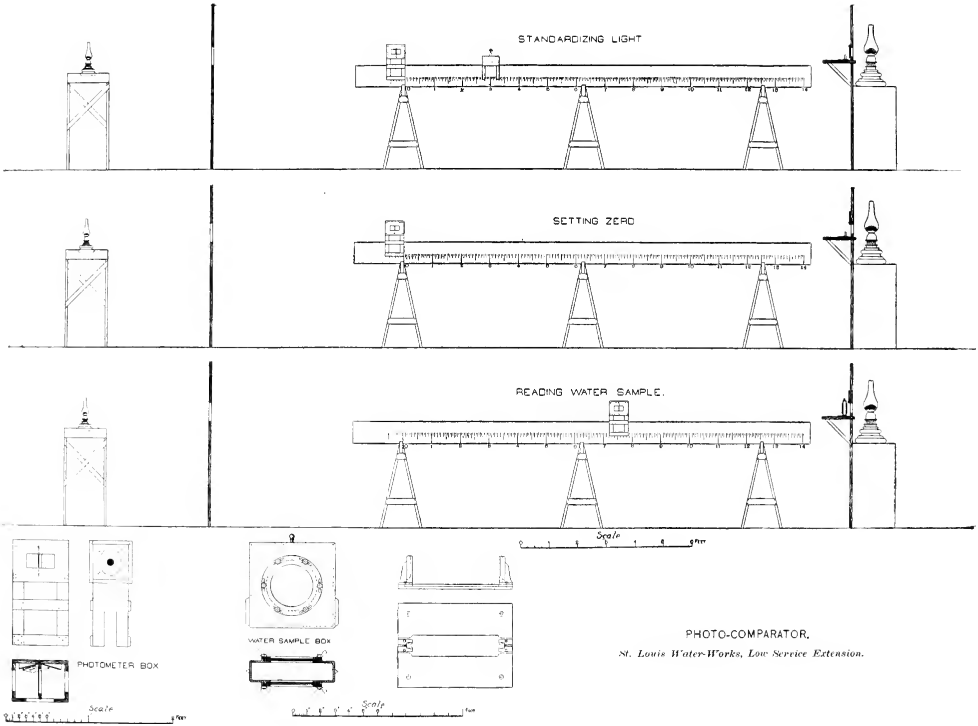


PHOTO-COMPARATOR.

St. Louis Water-Works, Low Service Extension.

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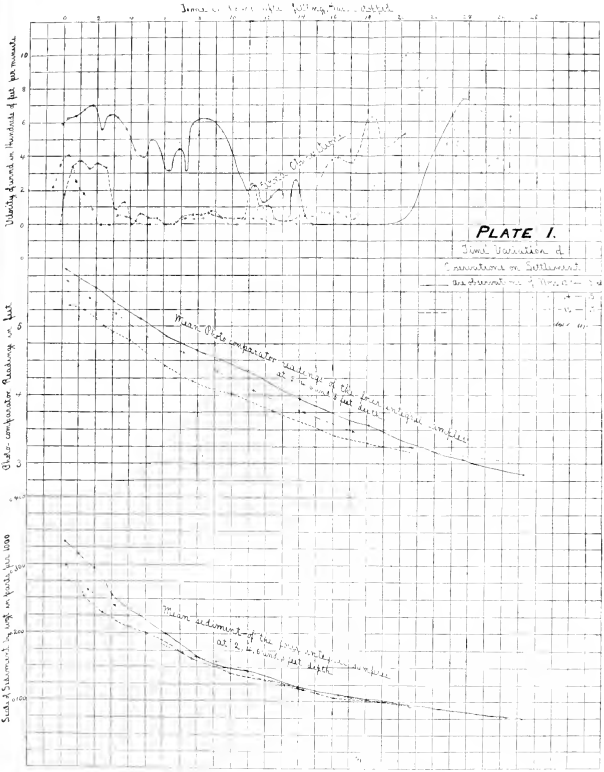


CLEARING WATER BY SETTLEMENT—OBSERVATIONS AND THEORY.

measured with an air meter, faced at intervals about to the wind, and not reading to velocities below 30 feet per minute, it is thought they give a fair representation of the actual wind force acting on the surface of the basin.

No definite effect of retarding the clearing can be assigned to the wind from this data, for though the photo-comparator readings in the November 14–15 observations, between 20 and 22 hours, seem to suggest a retarding effect, the corresponding sediment by weight data does not corroborate it, and later, when we would look for a like phenomena in the 12–13 data, it is not seen; nor with this exception can it be said that the effect of wind appears definitely anywhere in the general trend of clearing to time.

The data of these sets of observations, plotted for the investigation of the above theory of settlement, are presented on Plates II., III. and IV. As before stated, the test of the provisional theory is that V, or $\frac{d}{T}$, when plotted to δ, shall give one and the same curve for observations at the different depths, or that the same velocity of subsidence that was found for a value of δ from the surface to 2 feet depth should also be found to be the subsidence from the surface to the 4, 6, and 8 feet depths respectively. Instead of the data showing this to be the case, it shows very conclusively that it is not the case. That the value $\frac{d}{T}$ has a marked increase with depth for the same value of δ, giving distinctly different but well-defined curves for each depth ; and not only leading us to the conclusion that this provisional theory is wrong, but that settlement is altogether different from it : while at the same time the difference is clearly suggestive of definite law.

Two lines of investigation are here open to us: the empiric and the theoretical. In the first we may merely aim at the expression of the phenomena as observed, without considering their causes. On this line, from the data alone, we observe that there is quite a well-defined slant of δ for each series, given by the samples from 2 to 8 feet, and we might very fairly conclude that this slant was continued to the surface. We would, therefore, have a value of δ at the surface at that time, or which had not subsided at all. It would appear then that, instead of the points in δ starting to subside from the time that settlement commenced, they were retarded times respectively greater and greater as the values of δ grew smaller before they commenced to settle.

If we should call t the time from the commencement of settlement that a given point in density was retarded before it commenced to subside, then it would follow that its velocity of subsidence would be $V = \frac{d}{T - t}$ instead of $V = \frac{d}{T}$. With the above equation the data might have been worked, expressing as an empericism in each case the retardation and velocity of subsidence of the different points of δ, which would have been found to be fairly independent of depth, or defining one curve. The slant of δ for each series from 8 to 2 feet, with the curves for each depth of $\frac{d}{T}$ plotted to δ, are shown on Plates II.–IV.

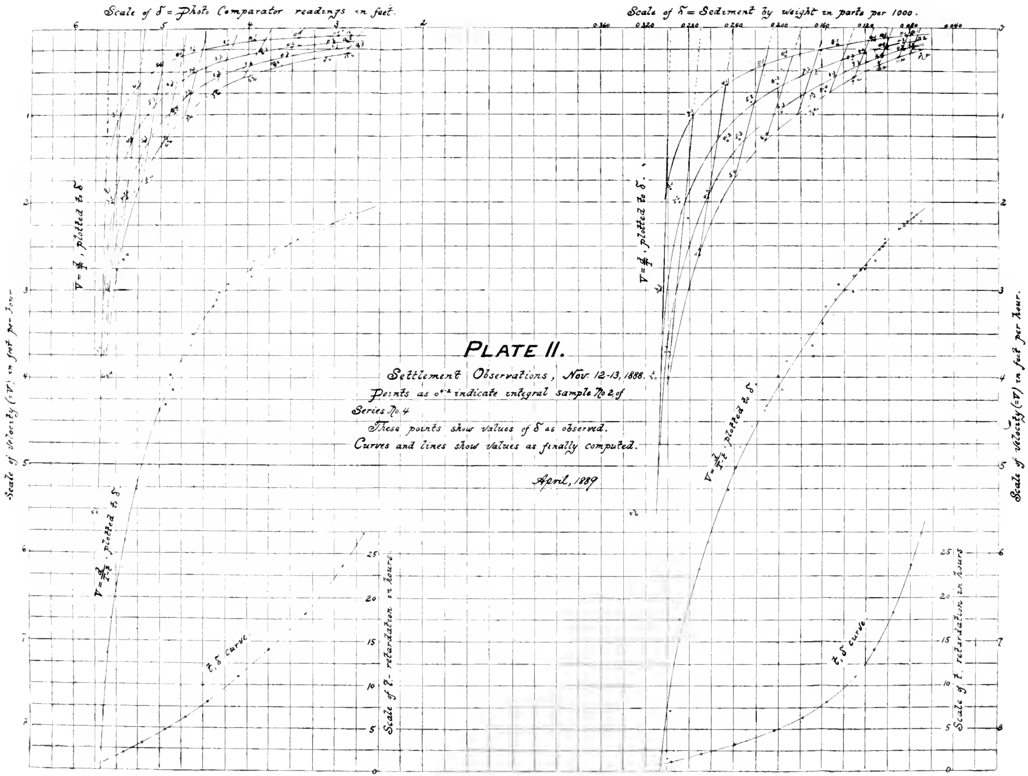
If, however, the investigation were confined to this empiric line, we would have no conception of the actual causes of this retardation or its method of operation. So that before taking up the working of the data, a theory of settlement on the suggestions offered will be considered; but first a review of the principal suppositions that would tend to explain the settlement as observed.

First. With the supposition that the more rapidly subsiding particles come in contact with others, which they carry down with them in their fall, it would follow that there would be a more rapid clearing at the bottom than that due to independent subsidence, as observed. But when we see that at the beginning of these cases of settlement there is not more than about one part of sediment by weight to 3,000 parts of water, and probably less than 1 to 4,000 by volume, while towards the end the proportion decreases to about 1 to 15,000, the prospect of particles occupying so small a part of the space, collecting to any considerable degree by contact during fal!, appears highly improbable, and this collecting would have to be large to in any way account for the observed phenomena.

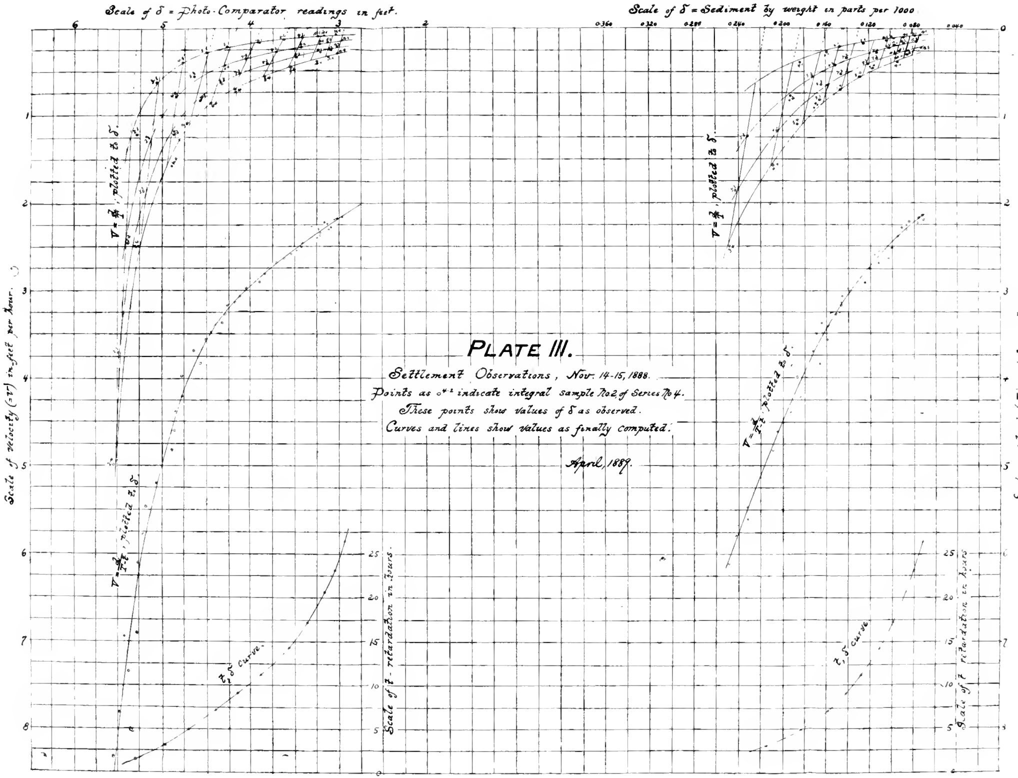
Second. The assumption that the particles have an actual acceleration of subsidence during their fall would explain the data. But there is no such thing in the fall of particles of observable size, no direct evidence of it has been seen in experiment, and it is difficult to conceive of how a force could act for any considerable time on a particle free to move without bringing its motion to the point where the force was in equilibrium with the resistance.

Third. Something similar to a coagulation acting, where there was a slow grouping of the particles into larger masses, which gradually reach sufficient size to fall, or fall with increasing size and velocity, would also be in the direction indicated by the data. But if coagulation were so prominent a phenomena in settlement, it is thought that the labratory experiment of class separation would have been impossible. The fact is, though, that the possible existence of coagulation acting to some extent is a difficult thing to either prove or disprove ; all that can be said is that in simple settlement without chemicals, so far no direct evidence of it could be anywhere seen, and that there are a number of suggestions against it. It is thought that a false impression in regard to it has arisen from watching settlement in a glass jar, or through a glass plate ; where a phenomena similar to it appears on the glass face, on which there is a process of surface settlement, that slides down at intervals collecting the particles before it, but which is no more like settlement than an avalanche is like a snow storm. This may be seen by looking into the interior of the jar by the aid of a beam of light, or by watching the settlement of a small quantity of sediment introduced into a bottle of filtered water. In fact, in the latter case the sediment, if started in small masses, seems rather to separate in its fall, and the velocity of fall, as far as it can be identified, seems uniform.

Fourth. By far the most probable explanation of the data is the retarding effect on subsidence of the internal motions of the water. If a jar of water were shaken up, at the end the water would in all probability have a motion as a whole, in the nature of a revolution in some direction. This would die out in a short time from side friction and conflict of cur-



CLEARING WATER BY SETTLEMENT—OBSERVATIONS AND THEORY.



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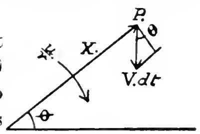
rents in the confined space, but after the bodily motion had disappeared there would still be visible a complicated system of internal motions, which could be watched for a long time in water, not too muddy, by the aid of a beam of light. In the same way in the basin. During filling the bodily motion is kept up by the flow of water from the filling point, but disappears soon after filling stops. It is thought that this bodily motion does not simply decrease indefinitely, but of necessity breaks up into internal motion by conflict of currents in the confined space. Otherwise we would have to assume that each element of water moved permanently in a closed path under balanced forces, which would appear to have one to infinity against it. We may infer then that soon after filling stops there is a considerable energy stored in the water in the form of complicated internal motions, formed during filling and by the breaking up of the bodily motions, which energy has to be slowly converted into heat by the friction between these internal currents.

In watching the basins during periods of muddy water, the break of these internal motions may be seen on the surface for hours after filling has stopped; and the fact that during settlement sediment is always found in the surface water can hardly be explained except by their effect.

To formulate a rational theory on this supposition, the uniform velocity of subsidence of a particle, combined with internal motion, will be mathematically considered. But first a general consideration of the forms of internal motion. While temporary rectilinear forms would be possible, interference could hardly fail to rapidly convert them into some of the forms of vortex motion, which, though neither circular nor fixed in position, yet as far as the average effect was concerned might be so regarded; also as a horizontal vortex, or the horizontal element of an inclined vortex, would have no theoretical effect on subsidence, only the vertical vortices will be considered. The discussion will therefore be confined to a range of vortex motion, considering the vortices a circular, vertical and with fixed centres.

The range that will be considered will be: I. The free vortex, where at any point the velocity is at right angles to the radius vector from the centre, and is equal to $\frac{u}{r}$, or decreases with the distance from the centre. II. The forced vortex, where the velocity at right angles is constant at all distances, say $= u$. III. Another form of forced vortex, where the velocity at right angles is ur, or increases with the distance from the centre. In all of these cases u is the velocity at unit distance from the centre, and the three cover a range of motion from the free vortex, which is that of a whirlpool, and is taken as a limit in one direction, through an intermediate case, to a motion where the water revolves about its centre as a solid wheel, which is taken as a limit in the other direction.

The following is the mathematical deduction of the equations to paths of a particle in these three cases.



Case I. Take P as a particle of sediment at the point $(\theta\ r)$ having a velocity of subsidence V. Then $V \sin \theta\ dt = - dr$ (1) the change in r in interval dt. We also have due to V an element of angular velocity $V \cos \theta\ dt = - r\, d\, \theta_1$, or the change in θ due to V is $-d\, \theta_1, = \frac{V \cos \theta\ dt}{r}$; also

from the vortex motion we have an element of angular velocity $\frac{u}{r}\,dt = -r\,d\,\theta_2$, or the change in θ due to vortex is $-d\,\theta_2 = \frac{u\;dt}{r^2}$. The total change in θ in intervals dt is $-(d\;\theta_1 + d\;\theta_2)$ or $d\;\theta = \frac{1}{r}\left(\frac{u}{r} + V\cos\theta\right)$ dt (2). The general equation to the path of P is gotten by eliminating dt between equation (1) and (2), or,

$$V\,r\sin\theta\,d\,\theta = \frac{u\;dr}{r} + V\cos\theta\;dr$$

or,

$$u\,\frac{dr}{r} + V\,d\;(r\cos\theta) = 0$$

or,

$$u\log_e r + V\;r\cos\theta\; = C \qquad I.$$

Case II. Where the vortex motion equals u only changes equation (2), of the above by substituting u for $\frac{u}{r}$ giving

$$u\,r + V\,r\cos\theta\, = C \qquad II.$$

Case III. Where the vortex motion is $u\,r$ changes (2) by substituting $u\,r$ for $\frac{u}{r}$, giving

$$\tfrac{1}{2}\,u\,r^2 + V\,r\cos\theta\, = C \qquad III.$$

Cases I. and II. are more simply calculated by converting the variables into a radius vector and an axis of X, in which they take the forms

$$\log_e r = C, - \frac{V}{u}\times \qquad I.$$

and

$$r = C, - \frac{V}{u}\times \qquad II.$$

where, assuming values of x, r is readily computed.

Case III. is seen at once to be the polar equation to a circle, with centre on the axis of x and at a distance $\frac{V}{u}$ from the vortex centre.

It is seen from these equations that, for a particle having a given velocity of subsidence, there are two elements that fix its path in a given vortex: First, the element $\frac{V}{u}$, or the ratio of the two velocities, and it is apparent that they enter as a ratio only in determining its path; second, an element C, which fixes the initial position of the particle in the field of the vortex. Paths of particles in the three cases are shown on plate V. for a given range of $\frac{V}{u}$, and for initial positions sufficient to show the general lines of movement. In cases I. and II. only paths in a single vortex are shown, but in case III. groups of vortices are shown. This case was taken to show the groups on account of its greater simplicity of construction.

We see from Plate V. that there is a field around the vortex centres where the particles move in a series of closed curves, whose eccentricity increases with the ratio $\frac{V}{u}$. It is apparent that whether a particle is permanently arrested in its subsidence by the vortex will depend on whether

its path lies wholly within the actual dimensions of the vortex. This will be clearer by considering the diagram where the groups of vortices of case III. are presented, showing the sediment settling out, and the sediment permanently retained in the vortex for the various values of the ratio $\frac{V}{u}$ It is apparent in this case that the condition that a sediment of a given value of $\frac{V}{u}$ should be all passing through the vortex, or that complete settlement of that class is taking place, is that the centre of the circle that the particle follows should lie on or outside of the circumference of the vortex circle, or that $\frac{V}{u}$ equals radius of vortex. In the case of I. and II. the conditions of complete settlement are not so apparent. It must be remembered, though, that in these cases the vortices must have an interior boundary, else the velocity would approach infinity towards the centre.

In the above discussion of the subsidence of particles through vortex motion, it is of course not at all meant that the particles actually follow any one of these paths; but as it is concluded that all the vertical angular motions of the water lie within the range of these cases, the actual paths, as far as vertical motion is concerned, must phase within this range, and a generalization that is true for all these cases must be true for the actual subsidence.

We may now formulate a theory of settlement on this view of the retarding effects of internal motion. A given class of sediment is fixed by the value V, which represents the velocity at which it falls in still water, also a given time after the basin is filled is fixed by the value u, which represents the velocity of vortex motion at that time. Now, if at a given time we consider a class of sediment where the value $\frac{V}{u}$ is such that complete settlement of it is just taking place, we see that in their fall, as an average, the particles meet as much of the up motion of the vortices as they do of the down, so that as an average they fall with their true velocity of subsidence, say V_1. At the same time also there is sediment of a smaller value of V, which is in part held in permanent suspension, and in part settling out of the vortices. The part settling out, however, is meeting as an average more of the down motion of the vortices than of the up; so that it is settling faster than its velocity of fall in still water. Continuing down the scale of sediment on decreasing values of V, we see that there are less and less amounts of sediment settling out at this time with the class V_1, but meeting as an average in their fall respectively greater and greater amounts of excess of the down motion of the vortices. We therefore take as a theory of settlement that at this time there is a group of sediment composed of respectively smaller and smaller amounts of the classes from V_1 down, which group has just commenced, and continues to settle with the velocity V_1. That prior to this time settling groups have been formed with velocities of subsidence greater than V_1, and following the groups have velocities smaller than V_1; the sum of all these groups making up the value δ_1, or the original density of sediment.

It should be noted that while the absolute value of a group and of the classes in a group depends on δ, and the range of classes in δ, yet the per-

centage of the classes contained in the groups is independent of δ, being fixed by the settling areas of the vortices; or the lap of classes that form the groups, which commence settling out after given times of retardation, depends on the law of dying out of the internal motion of the water. If, then, we suppose the classes, instead of being arranged in order from A to X, as in the first theory, were arranged with this lap of classes, we would still have a curve $A\ Z_1$, representing the velocity of subsidence of each point in δ_1; but in addition to the first theory we would have the conclusion that each point of δ was retarded a time t before it commenced to settle, and the velocity of subsidence of the points would be given by the equation $V = \dfrac{d}{T-t}$

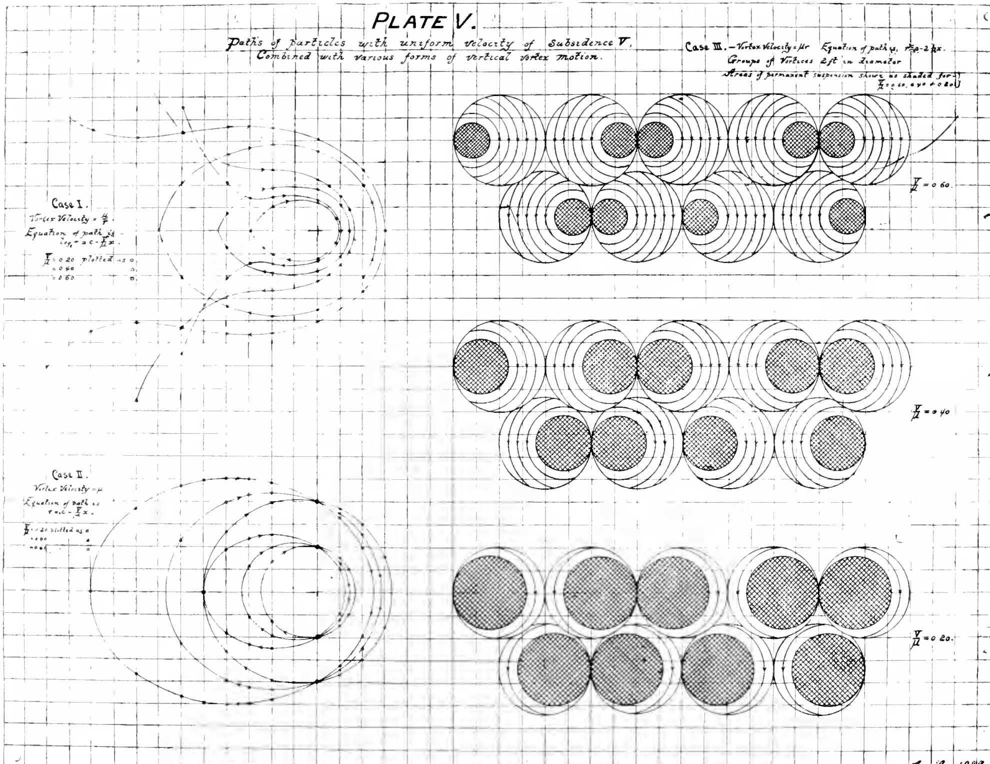
With this theory of settlement the study of the observations was taken up. For the determination of the time of retardation t, corresponding to the points in δ, the method before suggested was used. The slant of δ from 8 to 2 feet depth in a series was projected up to the surface for the value of δ at the surface corresponding to the time of that series, and this value of δ found at the surface at the given time would of necessity be the value that had been retarded up to that time, so that the time when the series was taken could be immediately plotted as the retardation of that value of density. In this way one point in the retardation (t, δ) curve was gotten for each series and the curve sketched in. This method is simply working the equation $V = \dfrac{d}{T-t}$ at the point where $d = o$, from which it follows $T = t$.

The slants from 8 to 2 feet depth drawn full, and dotted from 2 feet to surface, are shown on Plates II. and IV. as finally computed, and below are the corresponding retardation (t, δ) curves. These curves immediately show what a small part of the time a value of δ is settling, compared with the time that it has been retarded, and also the rapid increase of retardation as we approach the smaller values of δ.

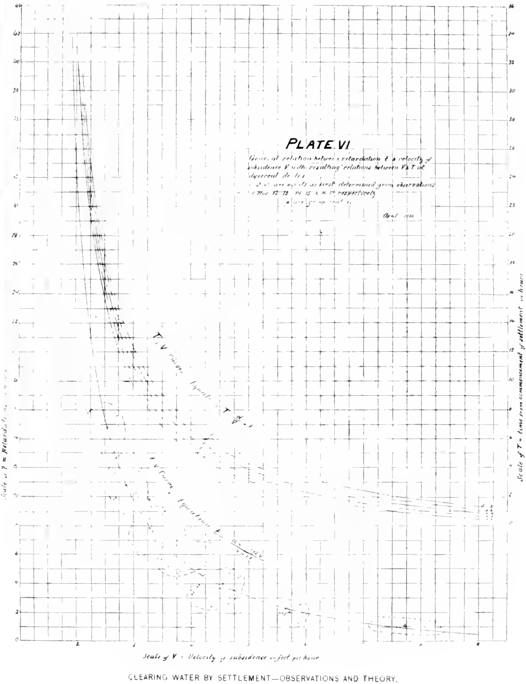
With the t of any density known, the V of that density could be quickly worked from the equation $V = \dfrac{d}{T-t}$, and the curves of subsidence, or the V, δ curves, plotted direct; but before considering these special curves there is another relation to be investigated.

The curve of subsidence, like the curve of retardation, expresses the special phenomena of the clearing of a given kind of muddy water, for their form depends in part on the absolute value and grade of classes in δ. But when we take the relation between the velocity of subsidence and the retardation from point to point in δ, we eliminate δ and get a relation independent of the special kind of water; that is, the velocity-retardation relation or the $V\,t$ curve.

To state this on the theory of settlement under consideration, we have in the $V\,\delta$ relation a given point in δ when starting to settle, representing a class of sediment that has a given velocity of fall in still water, say V_1, which class is just meeting complete settlement, combined with a fixed lap of sediment of smaller classes that settle with it at the velocity V_1. We also have in the $t\ \delta$ relation the fact that this given point in δ is retarded a time t before it commences to settle; so that the time t gives the



CLEARING WATER BY SETTLEMENT—OBSERVATIONS AND THEORY.



CLEARING WATER BY SETTLEMENT—OBSERVATIONS AND THEORY.

time that a sediment whose velocity of fall in still water is V_1 has to stay in the basin before it meets complete settlement, or it is the relation between a special kind of sediment and its retardation, independent of the amount of this kind of sediment in the water. In other words, it depends solely on the rate of dying out of the internal motions in the basin. This relation, therefore, when determined should be the fundamental law of settlement under this theory, and hence constant, in so far as the basin is undisturbed after filling.

The calculated velocities were plotted to retardation in the three sets of observations for a test of this relation. But from the equation by which V is calculated, $V = \frac{d}{T-t}$, it is seen that where the difference between T and t is small, and t is changing rapidly to δ, small errors in δ would make considerable errors in t, and might thus cause very large errors in the calculated values of V. For this reason approximate corrections were first applied to δ before calculating V. Then four or more of the simultaneous values of t and V were grouped for mean values, which were taken for points in the relation for each respective set of observations. These points are shown plotted on Plate VI. The observations of Nov. 12–13 are shown as .[1], of 14–15 as .[2], and of 16–17 as .[3]. These points are somewhat scattered, and to some extent a difference between the sets is suggested: but with a full appreciation of the necessary errors involved in the method of calculating V, it is thought that this divergence is no more than might be fairly assigned to this cause. The fairness of this assumption may be seen in the curves and lines of slant of δ shown on Plates II.–IV.; for these were finally computed on this assumption, and they fit the observations very well, while the points plotted on Plate VI., and showing the divergence, were from a set of preliminary curves and lines that had been sketched in, and which, when contrasted with the computed set, could not be said to have any advantage in their agreement with the data.

These points were, therefore, grouped as shown on Plate VI., and the emperic equation $t = \frac{20.4 - 1.92\ V}{V - 1.5}$ computed from the group centres.

With this relation known the value of t may be substituted in the general equation of the theory, giving an equation between depth, time of standing, and velocity of subsidence, as follows:

$$V = \frac{d}{T - t} \text{ or } T = \frac{d}{v} + t, \text{ or}$$

substituting the value of t

$$T = \frac{d}{V} + \frac{20.4 - 1.92\ V}{V - 1.5}.$$

The curves of this equation for depths 2, 4, 6 and 8 feet respectively, or the depths at which observations were taken, are drawn on Plate VI., the curve for zero depth being, of course, the t V curve.

From these curves the velocity of subsidence under this theory was scaled for the corresponding T and d of each sample, and plotted to the obserbed density of the sample, giving the points and $V\ \delta$ curves so indicated on Plates II.–IV.

A word in regard to these plates. We have on first theory V, or $\frac{d}{T}$,

plotted to the observed values of δ, and that all these points should define one definite curve, the condition that this theory is correct. Seeing that this is not correct, and considering the $V\,t$ curve expressing the rate of dying out of internal motion determined once for all, we have on the second theory values of V calculated as in the first from T and d alone, and plotted to the observed values of δ. The condition of the correctness of this theory being the same as in the first, that the points so plotted should determine one definite curve, which they very fairly do; we must then accept this second theory as the law of settlement. As a qualification to our acceptance we should, however, note that all the data were first used as a means to determine the $t\ V$ relation, on which relation rests the V^s as computed from T and d. So that from this data we can only accept the theory as more than an empiricism to the extent that we can consider the characteristics of the muddy water in these three sets of observations as differing from the mean characteristics. However, a set of observations that were taken later, on much more muddy and slow settling water, though not as yet worked up with the care of these, were investigated enough to see that they would give about the same result.

For my own part I do not much question that the above is about the general law of settlement for at least approximately the first 36 hours, and for all volumes comprised in the problem of settling basins. In regard to the effect of volume, use was made of some observations on settlement in a 36-inch pipe, 12 feet long, set vertical, taken under the direction of Colonel Flad. Though the method of measuring δ in these involved a large probable error which prevented them from being closely worked, they were yet sufficient to show essentially the same phenomena; and though possibly a somewhat less retardation of a given velocity of subsidence, it was largely an open question whether it really was less.

This is rather to be expected from the theory of settlement, for it assumes that this retardation depends on the rate at which the energy is being converted into heat by water friction between the internal currents, and this would be taking place through the whole mass; while the effect of the bounding surface would not be much more than a differential element of it, or the part of the energy lost on a surface plane. It is, therefore, not unreasonable to suppose that shape and size have not much effect on this retardation. At the same time we know that on the scale of laboratory experiments the settlement is more rapid; so that we infer that this small effect of bounding surface only holds down to scales where the formation of free dimensions in the forms of vortex motion is not checked.

This theory of settlement is in accord with the laboratory experiments in the separation of classes, for we would conclude that the groups that settled out before the time limits taken, contained a considerable range of sediment of slower settlement, but in each shaking up with filtered water the density of these slower classes was greatly reduced and the settling areas remained the same; so that, while never wholly eliminated, they became after four or five settlements very insignificant in quantity, leaving a very well-defined range in class.

It will be noted that on Plate VI., in taking the mean of the points of the three sets of observations in determining the $V\ t$ relation, it was tacitly

assumed that in each of these cases the basin received no disturbance after filling, or that the wind effect was immaterial. This point was not overlooked when the data were worked, but it was concluded that no definite effect could be there assigned to the difference of wind, and the assumption is borne out to the extent that the computed δs, shown at the intersections of curves and lines of slant, agree with the observed δs.

For the wind to have no effect we would conclude that the simple wave motion existing over the greater part of the basin was in itself no hindrance to settlement, and that the revolution of the basin, produced by the tangential force of the wind on its surface, was insignificant compared with the effect of internal motion. It is hardly thought that this question of the wind effect is settled by the data, but it certainly shows much less than might be expected, and was a great surprise to me.

In what has preceded, the main object has been to reach from the study of a very carefully taken series of observations a knowledge of the actual processes taking place in settlement; because such knowledge gives us a solid basis for the consideration of a large field of problems that are now speculative. And while it is not thought that the theory of settlement here deduced is sufficiently established to rely solely on conclusions from it, yet it certainly is enough to require very clear data before accepting conclusions in opposition to it.

But, leaving theory out of the question, the data alone were enough for the economic design of the settling basins; for they show as a fact in all case that there is not much difference between the clearness from top to bottom of the basin, and, for settlement beyond 24 hours, so little that the problem in St. Louis was practically one of economic storage of volume, and that an expensive covering to protect the basins from wind was not justified. As the economy of settlement by filling and drawing, contrasted with continuous flow, had been demonstrated by a former system of experiments, the above furnished all the information needed.

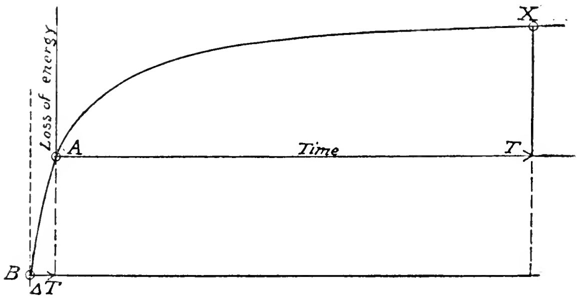
From the discussion of the above paper, the following has been added as perhaps throwing light on obscure points:

With the data alone we would only get the idea that a given class of sediment was retarded a given time, and I have been unable to imagine any actual process by which this could be effected; while with the theoretic discussion that was objected to we may very fairly see the actual process: that not the class, but a varying percentage of the class, is retarded at each time, making the explanation of the phenomena a process of straining out of particles of different size, in given percentages, at all times. This, of course, makes no difference in the facts, but might make a great difference in any general conclusions from them.

In considering the effect of the original disturbance, especially in the present St. Louis settling basins, there seems to be a lack of a clear conception of how motion in a fluid is stopped. It is a very simple thing to stop a car, because the parts hold together; but where there is an infinitely small cohesion between the particles of a mass, stopping its motion is another thing. We may represent the dying out of the energy in a given fluid mass by the following diagram.

With the mass having at any time the energy A, it would follow the

curve $A X$ in its loss of energy. If it had more energy, say B, it would come to the condition A on the curve $B A$, the time ΔT of which would be insignificant in comparison with the time T from A to X.



In regard to aeration, I must say that I do not see how it is going to help very fine particles of sand to fall. If it does, it must act on the water in some way so as to produce a coagulant; and, from the chemistry of our St. Louis water, I do not think this hopeful. At any rate, it is a point that could be settled very simply by experiment, and until its advocates are willing to take the trouble to make such experiments, it seems to me that they should not expect their assertions on that subject to be taken for facts.

HENRY C. MOORE—A MEMOIR.

By E. D. Meier, Member Engineers' Club of St. Louis.

[Read May 15, 1889]

The early dawn of the 13th day of April brought to a brave man in our midst the only relief he could hope for. After months of suffering, borne with the courage and stoicism so characteristic of the man, our friend, Henry C. Moore, laid down his burden.

Born Jan. 7, 1813, in Beaver, Pa., young Moore, at the age of eighteen, having profited by such meagre mathematical training as Western Pennsylvania academies and colleges then afforded, began his engineering career as rodman on the Beaver division of the Pennsylvania canals. Where now three railroads contend for the trade of the narrow but prosperous Beaver Valley, dotted with furnaces and forges, the State was then but beginning a single branch of its system of water ways.

Fifty-eight years brought many changes in engineering methods, and in the character of the works to which they were applied, and it was the fortune of our friend not only to see but to manfully share the work of the great development. The three-score years given as man's average span of life were almost covered by Moore's active work as an engineer. In eighteen months we see him as an assistant engineer, and two years later, his work there completed, he locates a canal from Lafayette to Terre Haute, Indiana. In 1836 he becomes Principal Assistant Engineer on the canals of his native State, and in three years more completes the 63 miles of "Erie Extension" canal from New Castle to Conneaut Lake Reservoir.

A turn in the wheel of politics now throws him out of employment there, but he at once finds work in his line in Ohio, and soon after becomes resident engineer of the White Water Canal in southeast Indiana, and rises in 1842 to be its chief engineer and superintendent. But new highways of trade more suited to American enterprise are superseding the ancient water ways, and in 1849, in the vigor of his early prime, well equipped with the knowledge of the soils and rocks he is to level for the track of the greatest of modern conquerors, Moore begins building railways.

First, the strap rail, then the low T-rail, with its chairs and rough joints ; from Howe truss bridges on piers of piles, on slowly and painfully through the cast iron stage to the evolution of the heavy steel rail. with Sampson fishings, stone-ballasted track, steel cantilever bridges, etc.; from the 40-foot passenger car with its torturing. stiff-backed seats to the vestibuled palace trains of to-day, he has seen all the stages of development, and has argued and solved the many problems which confronted the engineers of the fifties, sixties and seventies, whose work now, in the fittest survivals, fills the text books of our American engineering schools. He builds from Rushville to Shelbyville, Ind., from Hamilton, O., to Indianapolis; next, in 1851–52–53, he locates and constructs the Indiana Central Railroad from Richmond to Indianapolis; thence locates from Indianapolis to Evansville, 155 miles, and grades 55 miles more to Washington, Ind.; next, as chief engineer of the Marietta & Cincinnati Railroad, builds from Athens to Marietta and the branch to Belpre; in 1859 he becomes Superintendent of the Western Division of the T. H., A. & St. Louis, and moves to our city; in 1864 he rises to the general superintendency of the entire road, now the St. Louis, A. & T. H.; in 1868 he takes charge of the Missouri Pacific Railroad, but just completed to Kansas City. Here in 1869 the change of gauge from 5 feet 6 inches to 4 feet 9 inches became necessary, and his directors ask him to do this in one week. His answer is the completion of the whole 309 miles in one working day, without the delay of a single mail train.

In 1871 he builds the St. Louis, Lawrence & Denver Railroad from Pleasant Hill to Lawrence, 61 miles ; next as Chief Engineer and Superintendent of the Indiana & Illinois Central he builds the 152 miles from Decatur, Ill., to Indianapolis, and remains with the road till 1880. In 1881 and 1882 he builds the 140 miles of the Indianapolis, Bloomington & Western from Indianapolis to Springfield, O.

We find him on our Club's record from 1881 till his death, and the year 1883 places him on the list of our presidents.

The salient points of his character as they impressed his life-long associates were his broad and sterling honesty, manifest alike in the accuracy and justice of his pecuniary transactions, in the directness and clearness of his professional work, and in his capacity for seeing the true relations of things ; his tender sensibilities shown alike to family, friends and employés; and his stern and uncompromising hatred of trickery and injustice.

Uncomplaining in the severest pain, gratefully appreciative of the ministrations of his children, fully understanding his malady and bowing to the inevitable, he died, as he had lived, a true type of American manhood.

In the rapidity and thoroughness of his work, born of the most thought-

ful and painstaking preparation, in the stern and unbending justice of his executive management, in his active interest to the last in all sound progress in our noble profession, in the cheerful and kindly sympathy which endeared him to his friends, we gratefully pronounce him a model engineer.

To his family he leaves as fairest legacy the story of his long and successful professional life and the remembrance of his manly virtues; that we cherish them both and take honest pride in inscribing them on our records will, we trust, be to them the truest evidence of our sympathy.

On behalf of the Engineer's Club of St. Louis.

ON THE CROTON VALLEY STORAGE.

By Samuel McElroy, Member Western Society of Engineers.

[Read 1889.]

A brief analysis of the points presented to the new Aqueduct Commission, as prepared for counsel in the recent hearings on the relative merits for storage, of the Quaker Bridge reservoir at the foot of the river, or additional reserve in the upper valleys, may be of interest to students in hydrology.

The case may be thus stated:

Storage Provided.—The Department now has in actual use, under construction, or adopted for construction, twelve lakes of 2,114 acres water surface and 1,670 million gallons draught capacity; Lakes Mahopac and Kirk, of 1,191 acres and 1,140 millions; Croton Lake, of 400 acres and 2,000 millions; Muscoot dam, of 1,200 acres and 2,500 millions, and reservoirs E, G and H, on the west, middle and east branches of the Croton, respectively, of 279, 400 and 814 acres surface, and 2,727, 4,004 and 8,500 millions capacity; total surface, 6,398 acres, capacity 22,541 millions.

The Quaker Bridge reservoir is proposed to be built, with a dam, at 200 feet above tide, ponding the Croton Valley at a point about 4½ miles below the Croton Dam. Length at river bed, 300 feet; at parapet, 1,300, which is 214 feet above tide, 179 above river bed, 266 above rock face at bottom of bed, and, probably, not less than 285 feet above solid rock, if found, at the lowest section.

It floods, including the Muscoot Dam, at the same flow line, 3,635 acres, and a pond length of 16 miles.

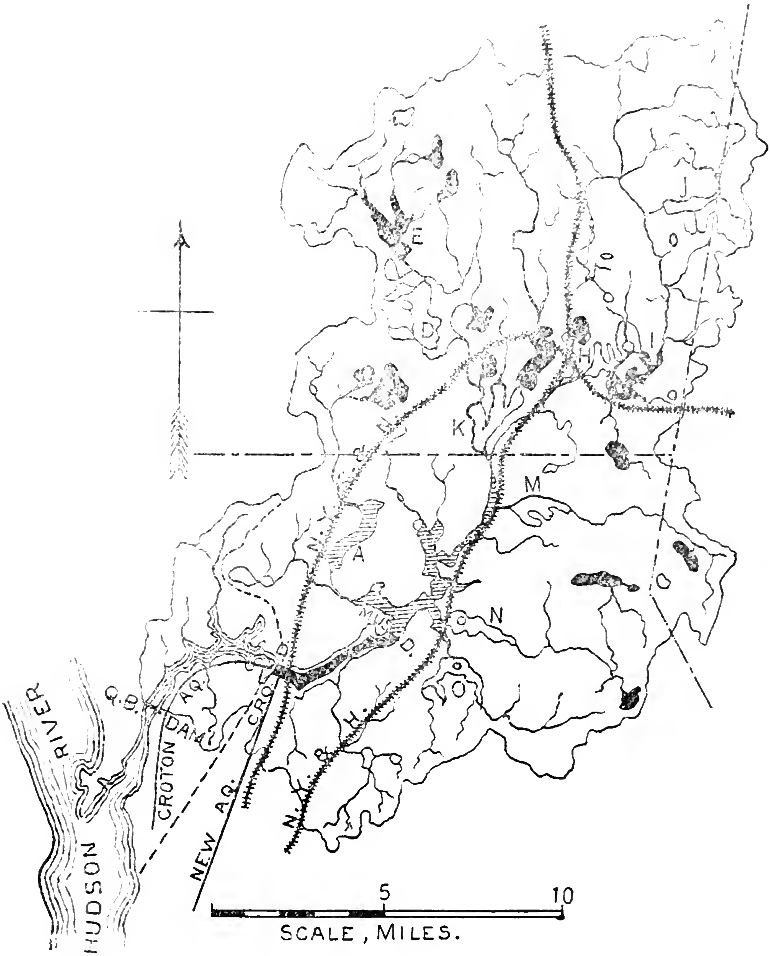
The flow line levels, above tide, are : Quaker Bridge, 200 feet, and Muscoot Dam ; Lake Kirk, 587 ; Mahopac, 658 ; Reservoir E, 600 feet ; G, 375 ; H, 375 ; the 12 natural lakes being all at high levels.

The relative catchment basins are : Quaker Bridge, 361.82 square miles ; Croton dam, 338.82 ; Muscoot, 300 ; Mahopac and Kirk, 6.19 ; E, 20.37 ; G, 20.90 ; H, 75.45 ; total, upper valley, controlled, 122.91 square miles.

Quaker Bridge impounds below the Croton Dam and above its present level, for 34 feet depth, about 10,380 millions; for 60 feet depth, 17,120 in all; between the Croton and Muscoot dams, for 34 feet depth, about 10,380 millions; total, 27,500.

City Conditions.—The several conditions of prospective population, demand, supply and reserve were taken as follows:

City Area.—Below Fourteenth street, 4.14 square miles; below Harlem River, less 1.71 parks, 17.7 square miles; city extension, less 5.78 parks, 13.37; total available, 31.07.



Croton Basin.

Reservoirs { *In use, Black.* *Adopted, Hatched.* *Proposed, Outlined.*

Future Capacity.—Below Fourteenth street the city had in 1840, 301,-058; 1850, 445,085; 1860, 499,000; 1870, 541,726; 1880, 405,007, the suburban growth having reduced the district since 1870. It held in 1860 about 108,700 per square mile; more than twice London ratio. In laying

out the future extension of Brooklyn the averages per square mile were 137½ blocks, 7,700 lots, to contain, at 14 per lot, 107,800 population.

At the ratio of 1860, New York will have, below Harlem River, 2,000,000, and above it 1,500,000.

Relative Time.—The population of the city proper was, in 1860, 813,609; 1870, 942,392; 1875, 1,041,886; 1880, 1,206,289; increase, '50 to '60, 58.5 per cent.; '60 to '70, 15.8; '70 to '80, 19.1; '75 to '80, 13.65 per cent.; assuming 25 per cent. from 1880, with a basis, including floating population, of 1,400,000, the amount will be, in 1890, 1,750,000; 1900, 2,200,000; 1910, 2,750,000; 1916, 3,200,000; 1920, 3,500,000.

Relative Demand.—The excessive and needless consumption and waste of certain large cities, as compared with those of Europe, and the restrictions of the future on available supply, must require an effective water police, and a much lower consumption than, New York 80 gallons, per capita; Boston, 87; Chicago, 114, or Washington, 176; the average of European cities being less than 30, and of Brooklyn 54. But, assuming 100 gallons per capita, with 20 millions per day from the Bronx, the daily demand on the Croton will be about, 1890, 1,550,000; 1900, 2,000,000; 1910, 2,550,000; 1916, 3,000,000 gallons.

Reservoir Head.—The distributing reservoir flow line of 115 feet above tide is now totally inadequate to the fire protection and domestic use of the city. Much relief will be felt in sections of the lower city, with a present available head of less than 20 feet, by the increased supply of the new aqueduct, but it cannot properly relieve what is now the enormous cost of elevating water to the upper stories of stores, office buildings, and residences, much of which is now done, not only by steam, but by very wasteful rams. Large waste will be relieved, but not the large pumping outlay, which, in some cases of single buildings, is $2,000 per year, and for dwellings, $100. The city could afford to spend $12,000,000 or $15,000,000 to relieve this burden.

High Service.—For the relief of two small districts, the city erected, in 1869, a pumping station at High Bridge, which lifts nearly 6,000,000 gallons per day about 100 feet, and in 1880, a second station at Ninety-sixth street, which lifts about 8,500,000 gallons about 60 feet at an annual cost of about $32,000.

It will cost to pump from the new aqueduct about 86,000,000 per day to a head of 250 feet, for engine house, etc., about $800,000; reservoir, $500,000; lands and contingencies, $300,000; plant, $1,600,000, and at 5 per cent., on an annual cost for pumping of $390,250, the representative capital is $7,805,000, or a total of $9,405,000.

The entire cost of the original aqueduct and city reservoirs, exclusive of distribution, was $7,983,504; it will be much better and cheaper, then, to build a high service aqueduct, with about 50 feet fall, and as nearly all the storage reservoirs of the valley are much above the requisite level, this is readily supplied. The construction of the new aqueduct, at a cost exceeding $20,000,000, with no gain in head, was a mistake, as would be that of any additional storage reservoirs below 300 feet above tide.

City Storage.—The high service reservoir at High Bridge has 216 feet flow line and 11 millions capacity; the proposed Bronx supply reservoir at Williams' Bridge has 180 feet level and 100 millions. The low

service 115 feet reservoirs are Murray Hill, 21 millions; Manhattan, 150 millions; New, 1,029; total city reserve, 1,311 millions.

Croton Capacity.—In his report of February, 1882, page 6, Chief Engineer Newton estimates the annual value of the Croton at 265 to 270 millions per day, if the Quaker Bridge dam is built to increase the drainage basin 23 square miles. With that opinion, why an enormous expenditure was advised and incurred for an aqueduct of 14 feet diameter and 324 millions capacity, on a line nearly parallel with the old aqueduct, with its capacity of 100 millions easily and cheaply doubled, it is difficult to understand.

The mean river supply reported by him is for 11 years, 1871–1881, about 357 millions per day, one year, 1880, being only 246; another, 1881, 295; another, 1872, 305.

But the late system of measurements at the Croton dam, made but once a day, and at a station about 75 feet above the dam, justifies his criticism on their value, expressed p. 44. Certainly no hydraulic engineer could accept such records as conclusive on either minimum or maximum flow, and with a mean rainfall of 46 inches on 338.82 square miles, the river should be worth about 445 millions per day.

But in a valley admirably adapted to agriculture, manufacture, and suburban population, with large centres now located, and already traversed by important railways, which has an inalienable right to its own water supply, water power use, and sewerage, a limit must be imposed on the draught for the Croton aqueduct, which will grow less, generation by generation. The standard of 300 millions per day has therefore been assumed in this discussion, as the limit to this draught up to 1916.

With these premises we can examine the question of storage provision at issue.

DEPARTMENT STORAGE ESTIMATE.

The chief argument in favor of the Quaker Bridge dam is based on the claim that in this way only can the cheapest and most adequate storage reserve be impounded; and to supply New York with 300 millions per day, the dry-weather flow is so small that a reserve of 69,905 millions is necessary, of which the city has a present storage of 9,000, leaving 60,905 additional to supply, of which this dam will impound for use 32,000.

This argument is based on the following table of the drought of 1880–81, which is offered as the correct standard of construction, and was furnished me for examination.

This tabulated storage estimate confronts us with a radical difficulty at the outset. If May to February 11, inclusive, are to be held as dry months, requiring storage draught, the city must be supplied, and the reservoirs filled in February, March and April, which, according to the reported flow and storage of 1880, amounted to 55,258 millions. If, then, during these ninety days the city must have 27,000 millions, there are left only 28,528 for reserve, a conclusion fatal to a storage of 69,000 and a supply of 300 millions per day on that theory, or to any adequate impound in the lower reservoir, if the upper reservoirs are properly used, with the total 22,541 capacity they actually hold.

For January, 1881, and especially for February, the table itself requires some corrections, which have been made in proper columns.

To determine how far this extraordinary table of 1880 can be used for probable dry month deficiency, up to 200,000,000 and 300,000,000 supply,

NO. 1.—FLOW OF CROTON RIVER, DROUGHT OF 1880–81.

Month.	Supply, millions.	Storage draft.	Net River Flow.	Storage Required. 200 m. per day.	Storage Required. 300 m. per day.	Corrected. Supply as measured.	Corrected. Actual use.	Corrected. Storage Draught Required. 100 m.	Corrected. Storage Draught Required. 200 m.	Corrected. Storage Draught Required. 300 m.
1880.										
May	5200	......	5200	1000	4100	5200	3107	....	1000	4100
June	3036	915	2121	3879	6879	2121	2986	865	3879	6879
July............	3102	1145	1957	4242	7342	1957	3028	1071	4243	7342
August......	3059	1990	1069	5130	8200	1069	3059	1990	5131	8231
September........	2956	1705	1211	4788	7788	1211	2961	1750	4789	7788
October..........	3043	2320	723	5476	8576	723	3043	2320	5477	8576
November........	3184	60	3124	2875	5875	3124	3004	......	2376	5875
December........	3080	335	2745	3454	6554	2745	3028	.	3455	6554
1881.										
January..........	3993	470	3528	2676	5776	3993	3039	......	2207	5307
February 11......	1098	225	873	1326	2426	mo. 18,126	2796	......	......	......
				34,850	63,550			8016	33,057	60,652
Ten per cent	......	......	......	3485	6355					
				38,335	69,905					
Present storage..	......	......	......	9000	9000	Storage provided.			22,541	......
Additional.......	......	......	......	29,335	60,905				10,516	38,116

the river experience, as it is reported by the department, has been collated in the following tables, based also on rain supply, as given by the West Branch gauge.

From the rainfall kept at Boyd's Corners, a point about 24 miles above the Croton dam and 550 feet above tide, it appears that the average fall for twelve years was 45.98 inches. For this period, December shows the lowest aggregate and August the highest. From observations at the Croton dam, the lowest supply reaching it was 45 per cent. in 1871, and the greatest 74 per cent. in 1868, the average being 57.68 per cent. for eleven years, or 26.51 inches flow of 45.98. Apparently the extreme monthly range during this long internal is from December, 33.29 inches, to August, 64.38, or not 100 per cent., and the surplus falls just previous to the two months when in usual experience it is most needed.

NO. 2.—RAINFALL—CROTON BASIN, 1866–77—TWELVE YEARS.

Month.	Monthly Rain. Mean.	Monthly Rain. Aggregate.	Monthly Rain. Min.	Monthly Rain. Max.	Annual Rain.		Per cent. flow at Croton Dam.
	Inches.	Inches				Inches.	
January	3.45	41.34	1.42	6 96	1866	51.77	51
February..................	3 18	38.10	0.80	6.40	1867	50.77	65
March	3.91	47.14	1.49	7.66	1868	50.33	74
April.....................	3.75	44 91	2.11	6 31	1869	48.36	58
May............	3.85	46.05	0.85	8.79	1870	44.63	47.5
June	3.70	44.41	0.71	5.73	1871	48.93	45
July	3.82	45.85	2.13	5.25	1872	40.74	49
August.	5.37	64 38	1.20	10.33	1873	43.86	67
September.................	3.76	45.24	1.44	9.33	1874	42.37	63
October.	4.43	53.16	1.50	9.46	1875	43.21	59
November..................	3.92	47.91	2.43	8.16	1876	40.68	56
December	2.81	33.29	1.49	5.96	1877	46.03	..
	45.98					45.98 average.	57.68 average.

1870—Least fall, December, 1.49 inches. Greatest fall, February, 6.40 inches.
1871— " " September, 1.44 " " " October, 6.18 "
1875— " " May, 1.08 " " " August, 10.33 "
1876— " " August, 1.20 " " " March, 6.33 "
1877— " " February, 0.80 " " " October, 8.38 "

Notes at dam taken by keeper; gauge about 75 feet above dam.

NO. 3.—MONTHLY SUPPLY AND FLOW OF CROTON RIVER—338.82 SQUARE MILES.

Month.	Twelve years mean. Rain.	Supply, millions.	River flow.	1878 Rain.	Supply.	River flow.	1879. Rain.	Supply.	River flow.
Jan..........	3.45	20,314	....	4.49	26,438	14,638	2.52	11,838	8,411
Feb..........	3.18	18,724	....	3.65	21,491	20,388	2.85	16,781	13,517
Mar...... ..	3.94	23,200	....	3.10	18,253	22,340	4.96	29,205	24,045
Apr..........	3.75	22,080	....	2.85	16,781	9,962	5.10	30,030	28,891
May.....	3.85	22,668	....	4.97	29,264	9,111	2.45	14,426	11,428
5 months....	18.17	106,986	....	19.06	112,227	76,439	17.88	105,280	86,292
June.........	3.70	21,700	....	4.65	27,380	8,131	5.29	31,148	4,864
July 15......	2.55	15,000	....	....	....	....	....	....	....
July 31......	1.27	7,500	....	4.28	25,201	3,800	5.95	35,035	3,805
Aug..........	5.37	31,620	....	2.66	15,662	3,801	5.83	34,328	6,381
Sept...	3.76	22,140	....	6.61	38,920	10,358	3.43	20,196	3,660
Oct 15........	1.48	8,710	....	....	....	....	....	....	....
Oct 31........	2.95	17,390	....	3.78	22,256	4,730	0.95	5,594	3,875
Nov..........	3.92	23,100	....	4.36	25,672	10,390	2.49	14,662	4,639
Dec..........	2.81	16,594	....	8.74	51,463	38,922	4.26	25,084	11,553
Year.........	45.98	270,740 57.68 p c	156.097	54.14	318,706	156,567	46.08	271.327	124,409 45.85 p c

Month.	1880. Rain.	Supply.	River flow.	Storage.	1881 Rain.	Supply.	River flow.	Storage.
				Reserve.				
January..........	4.00	23,496	16,087	....	4.19	24,671	3,993	470
February	2.92	17,152	16,938	....	5.28	31,090	18,126	225
March..............	4.51	26,491	17,764	....	6.14	36,154	35,282	....
April...............	3.99	23,437	12,038	....	1.67	9,833	10,370	....
May...	1.17	6,872	5,200	....	3.74	22,022	7,726	Reserve.
Five months.......	16.59	97,448	68,027	8518	21.02	123,770	73,497	7910
	......	....	76,515	....	......	....	81,407	....
			Storage included	Draught.			Storage included	
June...............	1.28	7,519	3,036	915	5.27	31,031	8,989	....
July 15............	3.76	22,125	....	......	......	....	....	Draught.
July 31............	1.89	11,063	3,103	1143	2.45	14,426	3,257	520
August......	3.60	21,146	3,059	1990	1.71	10,069	3,098	2260
September.........	2.69	15,804	2,961	1755	0.75	4,416	2,998	2700
October 15	1.08	6,363	....	....	......	....	....	2430
October 31..........	2.17	12,727	3,043	2320	13 65	21,492	3,098	....
November..........	2.97	17,445	3,184	60	4.50	26,497	3,044	....
December......	2.49	14,626	3 080	325	6.37	37,508	9 137	....
Year...............	38 52	226,266	89,493 39.55 p. c.	8518	45.72	269 209	107,118 37.79 p. c.	8605

Table No. 3, so far as the river flow is reported, depends on the correctness of the measurements given at the Croton dam. How far they are consistent with each other will appear on examination of both cold and hot months.

If the storage reservoirs were filled in 1878 and 1879 as in 1880 and 1881, the measurements at the dam for the first five months show, for 19.06 inches, 76,439 millions in 1878, and for 21.02 inches in 1881, 73,497; so that 112 billions net 76 in one case, and 123 net 73 in the other.

If we take the four dry months the result is as follows :

Rain supply.	July.	August.	September.	October.	Total
1878	25,201	15,662	38,920	22,256	102,039
1879	35,035	34,328	20,196	5,594	95,153
1880	33,188	21,186	15,804	19,090	89,228
1881	14,426	10,069	4,416	21,492	50,403
River Flow.					
1878	3,800	3,801	10,358	4,730	22,689
1879	3,805	6,381	3,060	3,875	17,121
1880	1,960	1,069	1,206	723	4,958
1881	2,737	838	298	668	4,541

Twenty-five billions, July, 1878, net, 3.8; 35 in 1879, 3.8; 33 in '80, 1.96; and 14.4 in '81, 2.7.

Twenty two billions in October, '78, net, 4.73, and 21.49 in '81, only 668 millions.

In July, '79. 33 billions, net, 3.8, and in October, the close of the hot weather effects, 5.59 billions, net, 3.8!

Comparing these results with those in Table No. 2, while the mean flow, measured, averages for 12 years 57.68 per cent., in no case is it less than 45, while the result in '81 is only 37.79; in '80, 39.55, and in '79, 45.85 per cent.

It is evident, therefore, on inspection, that the dry weather records of 1880 need modification. It is also singular that, whereas in usual city experience, New York not excepted, the time of greatest demand is at the season of extreme cold, to protect house pipes by night waste, and exercises a marked effect on all city reservoirs, nothing of this appears in the reported monthly consumption.

It becomes necessary, therefore, to construct a table correcting the conclusions of the department for 1880, and indicating more consistently with usual storage experience, what must be provided for in so low a year of rainfall.

As to extreme low run of the Croton the following measurements are quoted:

"The quantities running in the different streams enumerated, at the lowest season of the present year, were ascertained by gauging with great care, on the 4th, 5th, and 6th day of September. There had not, at that time, been an entire rainy day in the vicinity since the 3d of July. * * The results were as follows :

	Gallons per day.
Muscoot	3,628,800
Cross	9,142,400
Beaver Dam and Broad Brook	4,963,480
Cisco	2,073,000
West Branch	5,287,680
Middle "	1,452,000
East "	6,155,100
Total	32,503,760

"The testimony of the inhabitants as to the state of the streams at the time of gauging, compared with that of other seasons, was that the waters were 'very low, seldom lower,' and according to the statement of some, 'never.' The great drought of 1816 was the only one which was generally excepted in the comparison, and from the marks and indications shown me of the state of the water at that time, I was led to infer that they might have been fifteen, possibly twenty, per cent. lower than a the time of my examination."

The engineer therefore reduces the quantities to an aggregate of 26,002,-008 gallons.—*Report of Major D. B. Douglass, November* 1, 1833.

"The uncommon drought which prevailed in many parts of the United States during the last summer will be remembered for many years hereafter. That portion of Putnam and Westchester counties through which the Croton River passes has felt the effects of the dry season full equal, if not exceeding, any other part of the State; and the river was, consequently, remarkably low. In order to test the flow of the stream under these unfavorable circumstances, and to compare it with an unusually dry time in 1835 (? 33), Horatio Allen, Principal Assistant Engineer, made a gauge August 16th last, at two different stations. At the first there was found running 26,386,560 gallons; at the second 28,378,000 every twenty-four hours, averaging 27,581,780."—*Report Water Comrs.*, Dec. 31, 1838.

With these and other results in view, Table No. 4 is prepared to indicate the extreme allowance for hot weather losses, involved in so ample a rain supply as that of 1880 during this season; a season totally different from that of 1833.

In the measurements and examinations made by me of the Muscoot River for the Mahopac appropriation of 1878, it appeared that extreme low water occurred at Empireville of 10 cubic feet per second for about 20 days, and 25 cubic feet for about 57 days, equivalent to 198,383 gallons per day per square mile in one case, and 495,957 in the other; or for the Croton dam 67,216,000 gallons per day in one case and 168,000,000 in the other, or 2,016 to 5,040 millions per month.

NO. 4.—ANALYSIS OF RAIN AND RIVER FLOW, 1880—CROTON DAM.

MONTH.	Rain.	Per cent of year.	Amount per mo., millions.	Per cent. per mo. of year.	Flow per cent. of month.	Amount, million gals.	Reported.	Storage Reserve.	Deficit.	
									200 m. per day.	300 m. per day.
January	4.00	10.38	23,496	5.19	50	11,700	16,087	......	......	......
February	2.92	7.58	17,152	4.75	63	10,740	16,938	......	......	......
March	4.51	11.70	26,491	13.05	112	29,600	17,764	......	......	......
April	3.99	10.36	23,437	8.26	80	18,700	12,038	....	......	......
May	1.17	3.04	6,872	2.53	85	5,805	5,200	......	395	3,495
Five months	16.59	43.06	97,448	33.83	78	76,545	68,027 76,545	8,518 Draft		
June	1.28	3.32	7,519	1.66	50	3,760	2,128	915	2,240	5,240
July 15	3.76	9.78	22,125	3.75	38	8,466	......	......		
,, 31	1.89	4.89	11,063	1.25	25	2,822	1,959	1,143	378	1,978
August	3.60	9.34	21,146	0.75	8	1,690	1,069	1,990	1,510	7,610
September	2.69	7.00	15,804	0.42	6	948	1,212	1,755	5,052	8,052
October 15	1.08	2.82	6,363	0.23	8	509	......	......	2,491	3,991
" 31	2.17	5.62	12,727	0.57	10	1,272	723	2,320	1,928	3,528
November	2.97	7.71	17.445	3.86	50	8,728	3,124	60	......	272
December	2.49	6.46	14,626	3.68	54	8,298	2,745	335	......	11,002
Year	38.52	100.00	226,266	50.00	50	663,133	89,498	8,518	13,994	35,168
Storage provided										22.541
Additional										12,627

Subdivision of rain, July and October, in these tables, estimated.

In the above table the river flow of August is taken at 54,516,000 gallons per day; of September, 31,600,000, and half October, 33,933,000; mean for 76 days, 41,408,000 gallons.

Under the common ratio of 25 per cent. reserve, the annual supply of 109,500 millions would require 27,375. This table gives 35,168 : but it does so by extreme allowances for use, evaporation and absorption. The 16.59 inches of the first five months give a river flow of 78 per cent., or 76,545 millions, or 33.83 per cent. of the year, where 15.19 inches, July to October give 15,707, or 6.97 per cent. of the year, the flow for September dropping to 6 per cent. of the monthly rain. If 1880 had recorded no continuous rain from July to September, as in 1883, the analysis would show a far different percentage.

To show the probable action of the river for an average year of about 46 inches rain and 60 per cent. flow, Table No. 5 has been made.

NO. 5. ANALYSIS OF RAIN AND RIVER FLOW—CROTON DAM, 338.82 SQUARE MILES—12 YEARS MEAN—1866-1877.

Month.	Inches rain.	Amount.		Temperature.			River flow.			Deficit.	
		Millions.	Per cent. year.	Six years, min.	Six years, max.	1885 mean.	Amount.	Per cent. month.	Per cent. year.	200 miles.	300 miles.
January.....	3.45	20,314	7.50	23.4	36.8	29.8	10,154	50	3.75	......	......
February,...	3.18	18·274	6.92	24.9	39.3	31.1	13,540	72	5.00	......	......
March.......	3.94	23,200	8.57	29.1	43.5	36.4	28,500	1.23	10.53	......	......
April........	3.75	22,080	8.16	39.8	56.2	47.1	19,870	90	7.33	......	......
May.........	3.85	22,668	8.37	51.2	68.	58.9	16,644	80	6.14	......	......
Five months	18.17	106,986	39.52	......	......	......	88,708	83	32.75	......	......
June........	3.70	21,700	8.01	60.7	77.7	68.6	18,190	70	6.72	......	......
July 15......	2.55	15,000	5.54	......	......	......	9,000	60	3.33	......	......
July 31......	1.27	7,500	2.77	65.7	81.6	73.5	1,750	25	0.65	1,450	3,050
August.. ..	5.37	31,620	11.68	64.3	80.	72 1	4,743	15	1.75	1,457	4,557
September..	3.76	22,140	8.18	59.8	75.6	65.5	2,214	10	0.81	3,786	6,786
October 15 .	1.48	8,710	3.22	.....	......	......	871	10	0.32	2,129	3,629
October 31 ..	2.95	17,390	6.43	48.8	64.3	55.5	6,956	40	2.58	......	......
November. .	3.92	23,100	8.54	37.2	51.	42.8	16,170	70	5.93	......	......
December...	2.81	16,594	6.11	28.	41.2	33.3	13,752	83	5.16	......	......
Year.........	45.98	270,740	100.00				162,444	60	60.00	8,822	18,022

Storage Required.—The department table for a daily supply of 300,000,000 makes the storage 60.657, as corrected. For 1880, a proper analysis reduces this to 35,168, assuming in that case a flow in the dry season less than the measurements of extreme seasons. For a mean of twelve years this is again reduced to 18,022.

The expert conclusion was that it was wise to add reservoirs *A* and *D* to the present system, which would aggregate 36,782 millions capacity, at a cost for both based on Mr. Church's estimate of November, 1 888, of about $2,484,000. This would insure an ample supply for extreme y ears, as a question of reserve, and other special advantages contingent on upper valley storage, herewith presented.

Available Storage.—By request of counsel, an examination was made of

the several valleys, as occupied or proposed, with the result shown in the following table, No. 6.

No. 6.—Croton Valley Reserve.

Stream.	Reservoir.	Capacity, mill. Prism.	Available.	Surplus.	Basin area, sq. m. Required.	Available.	Surplus.	Area, acres.	Level above tide.
Muscoot River.......	Lakes Mahopac and Kirk.	1140	1140	......	4.60	6.19	......	1191	587
	A	5211	3926	1285	15.85	20.45	......	485	390
West branch...........	E	2727	2727	......	11.10	20.37	......	279	600
	D	9033	7640	1393	30.85	41.95	......	1008	500
Middle branch.....	G	4004	4004	......	16.29	20.90	......	490	375
W. and middle branch.	K L	8000	8000	3769	32 30	47 52	15 22	513	275
East branch............	H I	8500	8500	7872	31.32	66.11	31.79	834	375
	J	2314	2314	......	9 34	11.91	2.57	191	500
Titicus River...........	M	4392	4392	1389	17.73	23.34	5.61	492	316
Cross River	N	1676	1676	5991	6.76	30.96	24 20	197	250
Broad Brook............	O	......	2182	2106	8.81	17.32	8.51	240	305
	....	......	46,494	23,805	187 95	......	87 90	5830	
Croton Lake..........	....	....	1500 to 2000	....	6.05	......	......	400	
Muscoot Dam	....	......	2500	......	10.09	......	......	1200	
	....	......	50,492	......	204.09	......	......	7430	
Lakes included.........	....	......	1670	......	......	......	......	2114	
	....	......	......	......	......	......	......	9544	
Provided for............	....	......	22,541	Mahopac, E., G., H.; C. Lake, Mus. dam, lakes, etc.					

This table is based on an estimated flow of 78.4 per cent of rainfall of 18.17 inches, January to May, mean of 12 years, 1866 to 1877, at Boyds' Corners: the flow in 1880 being 78.15 per cent., equivalent to 4.038 square miles per billion gallons.

Under this basis for five months 204 square miles would be in use to fill these reservoirs of 50,494 millions capacity, leaving 134 square miles of the main stream (Croton dam), to supply it with 28,325 millions, or about 187.84 millions per day for these 152 days, using 14¼ inches of 18.17, and leaving a mean of 27.81 inches rain for the remaining seven months' stream run, in 45.98 total.

In other words, until the city uses 187 millions per day from the Croton, or until nearly 1900, this reserve can be thus supplied. In fact, the surplus flow of November and December makes a large reserve supply, not here included. The reported flow of 1880 for these five months is 76.150 millions in all, showing a spare storage supply of 45,750 millions at 200 use per day during these 152 days, for a year, which reports about 89,498 millions, against '07,802 in 1881.

High Service.—Of these reservoirs, J, H, K, G, D, E and A are 375 to 600 feet above tide. If an aqueduct is built, as it should be, for high service, a fall of about 50 feet will control over 300 feet head for special city distribution. For 250 feet head O and M will also answer.

Jurisdiction.—Actual possession of fountain sources is an exceedingly important matter in the future of all city supplies. The construction of these additional reservoirs of 28,454 millions capacity (with a valley capacity of 23,805 in addition), will give the city in all about 16 or 17 square miles area of actual ownership, and constructive control of much larger basin territory, a far more important consideration; and in view of the conflict, which is inevitable in the future, between actual property owners and a distant city, and the undoubted constitutional right of these owners to the full enjoyment of the rainfall, stream flow, domestic, factory, sewerage, agricultural, and other rights in these valleys, there can be no question as to the urgent need of actual ownership of all these reservoir sites, and their gradual construction for city use, since the supply thus gathered in the cold season has special advantages for control and use.

UPPER STORAGE ADVANTAGES.

These upper valley reservoirs catch the rainfall in the cold months, when it is in its best condition, from a primitive district of steep slopes, cleaner surface, quick descent, or from improved property, chiefly before farms are manured or surfaces likely to wash, and this they gradually purify as it accumulates. They secure a greater percentage of fall and of flow (Boyd's Corners reservoir [E], 14 years, 62.19 per cent., as against Croton dam, 57.68 per cent.), with more condensation, more forest and vegetation soil cover, less evaporation, absorption, tree and plant use, farm and valley wash, flood exposure, ice flow and risk to dams, less growth of basin population, manufacture, factory pollution, sewerage, road and railroad construction, property valuation and other contingencies of contamination and cost.

COMPARISON OF PLANS.

Assuming the limit of city supply from the Croton at 300 millions per day (taken by Chief Engineer Newton at 250), the city, at a recently estimated cost of about $2,484,000 for A and D, and $300,000 for the Muscoot Dam, can secure a total of 36,788 millions storage, which is more than is needed for such a supply in dry seasons.

As to quantity, quality and relative capacity, it is not necessary on these points to change the system of upper valley storage long pursued by the department.

Of the Quaker Bridge storage less than 14,250 millions will be needed.

The cost of this dam cannot be closely determined until the detail plans are definitely made. At the hearing it was distinctly admitted by the Board that such plans had not been prepared. A proximate estimate made by Mr. Church makes the amount $6,700,000, but does not include various items of construction and cost, while the prices for assumed items are too low. The Board of Experts, in their report of Oct. 1, 1888, estimate the base excavation and masonry of dam alone at $4,172,380, without lands, damages to structures and property, road and railroad changes, bridges, fences, subdams, soiling, and other large and unavoidable expenses. For the river-bed earth excavation they take 277,188 yards at $277,188, and 63,703 rock at $127,406. This must be made in a deep trench (87 to 106 feet) of porous material, exposed to the tide on one side and river and flood saturation on the other, requiring powerful pumping for about three years,

and working plant in pumps, dams, flumes, etc., of very costly character, for which $1,500,000 is a moderate estimate. The estimate for masonry, of $6, $6.60, $7 and $8, is also too low for the quality actually required for its enormous strains and the excessive height of the structure.

It is obvious, therefore, without close discussion, that the additional 14,250,000,000 required will cost less than one-third that of this dam in the upper valleys, and avoid the contingencies of great leakage through a metamorphous and treacherous base, and other probable contingencies of loss and damage.

As to time, the separate upper reservoirs can all be built in less than one-third that of the single, massive dam.

To fill the 14,250,000,000 required an area of 57.54 square miles would suffice; and for the whole, 27,500 millions, 111 square miles. As more than this area is directly available in the upper valleys, there is no special advantage in the 23 square miles below the Croton dam, compared with the character of the supply from the upper basins.

Sanitary Effects.—For storage supply from the first five months' flow of the year it is obvious that much less organic matter will be carried into the upper reservoirs draining their limited areas, than the same flow taken from the wash of the entire basin; and while the upper reservoirs will be better protected from flood wash in the hot months, no protection exists for a receptacle at the bottom of the whole valley.

As putrefactive fermentation, which is the common source of reservoir impurity, depends on the relative quantity and character of dead or diseased organic matter contained; there can be no question that a much larger and objectionable and more frequent supply must enter the lower receptacle than the limited and better protected upper reservoirs of different location and exposure. As a matter of organic quantity and quality the law of flow decides against the lower catchment.

With surplus reserve in detached reservoirs, proper care can always draw the depurated water for use from its distinct layers, or the best reserve for the time being; and the down stream flow, by subsidence, aeration, and soil action, will be a powerful corrective. With the Quaker Bridge reservoir in a state of noxious fermentation, similar remedies are impossible.

Much stress has been placed on the great depth and size of this reservoir, as opposed to this putrefactive action; but our deepest great central lakes show the same action at times, and the Gulf of Mexico itself. Nature's law of depuration must act wherever the process is needed, and neither depth, nor size, nor cold temperature can prevent it, if collections of dead or diseased organic matter, in bulk or in solution, are to be transformed into harmless constituents. The only wisdom is to avoid its reception as much as possible; certainly not to devise enormously expensive and unreasonable structures for its special accommodation. Every water supply in the country bears full testimony to the force of this proposition; the cesspool of the entire Croton valley cannot possibly be filled pure or kept pure, and it must be depurated by this process at the risk of the health and comfort of its city consumers.

Malaria.—Uncovering in the hot season large pond surfaces containing deposits of organic matter is a fruitful source of disease. The valley

area exposed here in drawing out 34 feet depth of water will be about 2,000 acres. This in itself is a formidable objection to the lower reservoir, since it must occur every year on areas specially liable to organic deposit.

Conclusion.—Since the hearings, at which Wm. E. Worthen, Chas. H. Haswell and Peter Hogan, civil engineers, Henry S. Welles and other experts emphatically indorsed the upper valley system, the board have resolved to proceed with the construction of Reservoir A, and ordered surveys of D, K and M for detail constructions plans, and indefinitely postponed the consideration of Quaker Bridge storage, as I am informed.

WILLIAM S. BARBOUR.—A MEMOIR.

By George A. Kimball, Albert F. Noyes and George E. Evans, Committee of the Boston Society of Civil Engineers.

[Read September, 18, 1889.]

William S. Barbour, City Engineer of Cambridge, and a member of this society, died at his home in Cambridge, Feb. 24, 1889. Mr. Barbour was born in Boston, Dec. 1, 1835. While he was an infant his parents removed to Cambridge, in which city he always resided. He attended the public schools and graduated from the High School with honor. In 1852, he entered Harvard College, Lawrence Scientific Department, where he studied his profession. In January, 1854, he entered the office of William A. Mason, Civil Engineer of Cambridge, and in 1855 was admitted as a partner. While with Mr. Mason he was engaged on the Cambridge, Metropolitan, Middlesex and Watertown street railways, also on street railway work in Worcester, Portland, Me., and Norwich, Conn. In 1857 the partnership was dissolved, and Mr. Barbour opened an office in Cambridgeport, and at a later date one in Boston. Both of these offices were retained until April, 1876, when he accepted the office of City Engineer of Cambridge During the last part of his private practice he was the senior member of the firm of Barbour & Hodges, and among the many works with which he was connected are the following: Coast survey at Fort Independence; Clarksburg and Staniford reservoir; wharf improvements in Charlestown; Marginal Freight Railway, Boston; Cambridge Water Works; Arlington and Winchester Gas Works; Caledonian Mine, Cape Breton; Holy Cross Cemetery, Malden; West Dedham & West Roxbury Railroad ; North Reading Railroad; Charles River Railroad; North Andover & Wakefield Railroad, and a system of railways for the transportation of lime rock at Rockland, Me.; and during the last five years of his private practice he had an extensive and successful experience in street railway work in Boston and vicinity, Portland, Me.; Norwich, Conn.; Haverhill, New Bedford, Fair Haven, Lynn and Worcester. To the subject of street railways he gave much time and study. This, together with his natural ability, placed Mr. Barbour at the head in this branch of his profession.

In 1876 he was elected City Engineer of Cambridge, which office he held until his death. Soon after his election he commenced an investigation of the "sources of pollution of the water supply and the means of preventing the same," and submitted a report September 28th, 1877. Mr. Barbour

was one of a special committe appointed by the city council to report on the Cambridge water supply. The investigation embraced the following subjects: "Present Water Supply, both as to Quantity and Quality," "Sources of Pollution, Present and Future," "Remedies." The result of the work was presented to the city council in December, 1879, and the report is a complete and faithful presentation of the subject.

In 1880 the subject of an additional supply of water for the city was agitated, and Mr. Barbour made the necessary surveys and examinations, which resulted in a recommendation from him for taking water from Shawshine River; but the Legislature refused to grant the right, and the water was finally taken from Stony Brook. A part of this work was described by Mr. Barbour in a paper entitled "The Dam of the Cambridge Water Works on Stony Brook," read before this society June 20, 1888. To this work of constructing the works necessary for an additional supply Mr. Barbour gave much time and thought, and it is the opinion of many that his untiring devotion, constant anxiety and overwork, in connection with this undertaking, hastened the disease which caused his death. While he was city engineer the sewerage system was extended and many street and bridge improvements were prosecuted under his direction.

Mr. Barbour was thoroughly devoted to his profession. An apt and careful student, he gave much time to his books, and was the owner of a fine engineering library. He was remarkably reserved in manner, conscientious, honest and fair in all his dealings; always courteous and obliging, with the kindest feelings toward all—to his subordinates, as well as those above him in authority.

In 1862 he married Julia H. Battis, of Roxbury, who survives him. He also leaves two sons—the elder a civil engineer and the younger attends the public schools in Cambridge.

Mr. Barbour was a member of Charles River Baptist Church, and at the time of his death was serving on a committee for the building of a new church. He was a member of the American Society of Civil Engineers and of the New England Water Works Association.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

SEPTEMBER 18, 1889.—A regular meeting was held at the Massachusetts Institute of Technology, New Building, at 19:35 o'clock, President Fitz Gerald in the chair, thirty-eight members and twenty two visitors present.

The record of the last meeting was read and approved.

Mr. Georgle L. R. French was elected a member of the Society.

The following were proposed for membership: Francis W. Dean, Cambridge, Mass., recommended by E. D. Leavitt and C. W. Kettell; B. R. Felton, Somerville, Mass., recommended by M. M. Tidd and F. C. Coffin; and George I. Leland, Lynn, Mass., recommended by H. H. Carter and G. W. Hamilton.

The Secretary read a communication from Mr. W. P. Shinn, chairman of a committee of the American Society of Civil Engineers, on revision of the constitution, suggesting the appointment of a committee to confer with the committee of the American Society, with a view of determining whether a satisfactory basis can be established for affiliation among the various engineering societies. The Government was authorized to appoint a committee of three to confer with the committee of the American Society and to report to this Society at the October meeting.*

Mr. Stearns, for the Committee on Revision of the Constitution, submitted a draft of a new constitution and by-laws. The committee was authorized to print the same and send it to members at once for suggestions.

Mr. George A. Kimball, for the committee appointed for the purpose, presented and read a memoir of William S. Barbour.

On motion of Mr. Albert H. Howland, the Secretary was requested to convey to the Boston & Albany Railroad Company the thanks of the Society for its kindness and generosity in permitting the Society to occupy rooms in its Boston station for the past four years.

Mr. Edward Sawyer then read a paper entitled, " Mills and Mill Engineering." In the discussion which followed on mills and mill construction the following gentlemen took part: Edward Atkinson, President, and C. J. H. Woodbury, Vice-President of the Boston Manufacturers' Mutual Fire Insurance Company; Edmund Grinnell of the New Bedford Iron Foundry; Charles T. Main, Superintendent of Pacific Mills, Lawrence; Stephen Greene of Newburyport; William F. Sherman of Atlantic Mills, Lawrence, and Vice-President Freeman, of the Society.

President Fitz Gerald discussed the matter of heavy floors of wood in their relation to fire-proof construction, and illustrated by reference to a recent fire in

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*The Government has appointed the following as members of that committee Frederick Brooks, Dwight Porter and Sidney Smith.

the Wheeler Building, on Kingston street, Boston. Mr. L. F. Rice described the construction of this building, which he had examined previous to the fire.

[*Adjourned.*] S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

SEPTEMBER 11, 1889, 310TH MEETING.—The club met at Washington University at 8:15 P. M., President Meier in the Chair, sixteen members and two visitors present. The minutes of the 309th meeting were read and approved. The Executive Committee reported the doings of its 76th, 77th and 78th meetings.

The Secretary read the letter of August 7, 1889, from Wm. P. Shinn, Chairman of the American Society of Civil Engineers' committee on revision of its constitution and by-laws. The letter suggested the appointment of a committee representing the Engineers' Club of St. Louis for the purpose of conferring with the American Societies' committee, with a view of determining whether a satisfactory basis can be established for affiliation between the American Society and the local organizations. The Secretary made a verbal statement of the consideration which had been given this subject by the Executive Committee in conjunction with the club's special committee on closer union of engineering societies. These deliberations had resulted in the following report:

Your Executive Committee recommend that a committee of three be appointed by the chair to confer with the committee of the American Society of Civil Engineers, and with other clubs, on a plan of union on the following basis:

All local organizations to become chapters of the American Society of Civil Engineers, and to have the exclusive right of electing to a grade similar to the present grade of "associates," subject to some general minimum scale of qualifications.

Such members of the local organizations as are not now members of the American Society of Civil Engineers to become "associates" by their clubs entering this union.

The only other grade of membership to be member of the American Society of Civil Engineers, and these to be elected as at present by the members of the American Society of Civil Engineers.

And further, in the event of a conference being called between other committees, that the committee of the St. Louis Club be authorized to send delegates to such conference.

Mr. Seddon made a verbal explanation of the committee's report. Mr. Russell read reports, which had been made by local members of the American Society of Civil Engineers in Chicago and in St. Louis. The sentiment was entirely favorable to the proposed affiliation. President Meier gave some further explanation of the different points which had been considered in committee. Mr. R. E. McMath suggested that the proposed action being of great importance, it could perhaps be more clearly understood and acted upon, by dividing the measure into three parts:

1st. Shall this club appoint a committee as proposed? 2d. If the club appoint a committee, shall it be empowered to send a representative to a conference? 3d. What plan of action, if any, shall this committee be authorized to promote?

He further moved that the chair appoint a committee on a plan of union, as proposed in the report of the executive committee. This motion being seconded by Mr. Robert Moore was on vote carried. Mr. McMath then moved that the committee be authorized, with the consent and approval of the executive committee, to send a representative to the proposed conference at the expense of the club. Seconded and carried. Mr. Robert Moore moved that the committee be authorized to act in the general line mapped out in the executive committee's report, as expressing the sense of the club. Seconded and carried. President Meier appointed as such committee Robert Moore, R. E. McMath and J. A. Seddon The

secretary announced an application for membership from H. M. Kebby, now engineer on the People's Cable Railway, of St. Louis. His application was indorsed by T. B. McMath, W. Bartlett and E. D Meier. F. M Crunden, librarian in the public library, being present, was invited to make a statement regarding the proposal recently submitted this club by the public library regarding meeting place for the club, and co-operation between the club and library. The question at issue was the requiring of members who already held life memberships in the public library to take out additional memberships with the club. After some discussion, in which Messrs. McMath, Long, Seddon, Hubbard and Bryan took part, the matter was laid over in order to ascertain the number of members affected by this point.
W. H. BRYAN, Secretary.

[*Adjourned.*]

ENGINEERS CLUB OF KANSAS CITY.

SEPTEMBER 7, 1889:—A regular meeting was held at Wallula, Kan., at 11:30 A. M., by invitation of Mr. H. A. Keefer, Vice-President Breithaupt in the Chair, Kenneth Allen, Secretary.

Minutes of the last regular meeting, and three meetings of the Executive Committee, were read and approved.

On motion of Mr. Mason it was voted to appoint a committee to confer with a committee of the American Society of Civil Engineers, and similar local committees, with reference to a closer affiliation among the various engineering societies.

The following resolutions of respect, prepared by Mr. Talmage, were read by the Secretary:

Whereas, We, the members of the Engineers' Club of Kansas City, have learned with profound regret of the death of our fellow member, Eugene J. Remillon, and

Whereas, We feel that in his death we have lost one of the brightest and most industrious members of our Club; and

Whereas, We appreciate his high character and thorough integrity; therefore

Be it Resolved, That we tender our heartfelt sympathy to his bereaved family, and express our high regard for his professional standing and personal character; and

Be it Resolved, That the above resolutions be duly entered in the records of the Club, and a copy thereof sent to his family.

A paper on "Water Gas" was read by Mr. A. G. Glasgow. The writer endeavored primarily to correct the very general misconception the public entertains concerning the ultimate possibilities of "Water Gas," by demonstrating that absolutely no thermal advantage is derived from the use of the gases obtained by the decomposition of steam. But, that for every unit of heat developed by the hydrogen thus obtained, an equivalent in carbon has been consumed in the generator. And further than this, that the use of steam is a source of actual loss, determining the percentage of heat thus lost. Incidentally, descriptions of the methods and modern apparatus for the manufacture of both fuel and illuminating water gas were given.

A paper was then read by Mr. H. A. Keefer on "The Early Manufacture of Iron."

Smelting by Egyptians, done without blast in furnaces similar to lime kilns. Use of iron spread over Europe until the downfall of Rome, when Spain produced all iron used until middle of eighth century. France and Germany then took up its manufacture in Catalan forges, furnishing from two to five tons weekly each.

Modern blast furnace appears about middle of thirteenth century, but England

did not supply her own demand until middle of eighteenth century. The blast was usually supplied by bellows worked by water-power.

1735.—Coking coal begun. Abraham Dally.

1735.—Cast iron blowers invented. John Smeaton.

1769.—Steam bellows invented. James Watt.

1783.—Puddling and rolling in bars. Henry Cort.

1820.—Puddling in France and Sweden begun.

1830.—Puddling in Prussia begun.

Treatment of ores described.

1644.—First successful furnace in America, near Lynn, Mass.

1740.—Iron manufacture taken up in New York.

1715–1770.—Great development in New Jersey and Pennsylvania; 300 to 400 tons per annum produced

Value of iron and steel produced in United States, 1888, far exceeded that of all other metals combined.

After brief discussions of both papers the following were proposed as Members:

John R. Braidwood, by F. C. Gunn and O. B. Gunn.

And as Associates:

Robert M. Sheridan, by W. H. Breithaupt and H. A. Keefer.

Thomas Ashburner, by W. H. Breithaupt and F. C. Gunn.

Thomas Callahan, by F. C. Gunn and A. J. Mason.

After an excellent lunch served on the lawn, the guests were most hospitably entertained by Mr. and Mrs. Keefer, with various out-door games until 6:30 when the train left for Kansas City.

[*Adjourned.*] KENNETH ALLEN, Secretary

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MILLS AND MILL ENGINEERING.

BY EDWARD SAWYER, MEMBER OF THE BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read September 18, 1889.]

The word "mill," originally designating a machine for crushing or pulverizing food materials and other substances, was afterward taken to include also the containing building with the motor apparatus and all the other appurtenances—to be, in fact, a short synonym for *milling establishment.* The fundamental distinguishing characteristic of such an establishment was that in it useful work was done by mechanisms actuated by power from without. Then the public—with its usual ignorance and disregard of etymological propriety—took the word *mill* as a designation for such establishments in general, even those for making textile fabrics, where the object was not to pulverize materials, but, on the contrary, to arrange them in certain orderly ways with the least possible injury to the fibres.

The word *factory* is a better one etymologically, but it is longer and less thoroughly assimilated from Latin. Its present employment, in connection with certain industries, seems to be a matter of usage or euphony rather than of any strong reason; and the same may be said of the word *shop*.

Thus usage has selected the word mill, as a generic term with specific prefixes: and as new industries have developed from time to time, new prefixes have grown on to it—without any order or system—indicating the scope of the business, the source of power, the product made, the process performed, or the material worked.

This movement was not confined to the English language only—substantially parallel ones occurred to a greater or less extent in the other principal languages.

Scientifically considered, this makes a bad jumble: but practically it involves little or no ambiguity. The prefixes tell the story fully and accurately enough, and their meanings are easily learned.

The evolution of the modern system of manufacturing on a large scale and on business principles is the work of this last century of progress. Approximately, 50 years were spent in the immediate preparations for it

and 50 more in its development. This system is one of the three great facts in the present industrial era, the other two being science and steam transportation by water and rail. All before this is the wilderness of hand work, into which Ruskin and Tolstoi and other well-meaning but deluded men imagine they wish to force us back by their talk.

In those old, hard times, the difficulty of transportation compelled each town to be almost a complete industrial system by itself: to do a little of almost everything in the way of supplying its own wants.

If we had time, it would be interesting to trace some of the principal facts and causes in the history of the growth of the mill system and its relations, both of cause and effect, with science and steam transportation; to follow the transition from the era of muscle-power and hand-work to the era of mechanical motors and machinery: which, though now well established, is still in its first youth; but, at the utmost, we can take only time to mention some of the more prominent factors in the case.

Among these must be reckoned, as a *sine qua non*, a full supply of irons at moderate prices. This want began to be met tolerably well by the introduction of mineral fuel in 1745, and of rolling-mills and puddling-furnaces in 1783 and 1784.

A better supply of power was equally needful—muscle is wholly incompetent to do the world's work satisfactorily. Wind-wheels and water-wheels could and did do much, but only a small fraction of what was needed for a high state of civilization, especially in the absence of steam transportation to carry supplies, materials and products to and from the places where water-power could be obtained.

The improvement of the stationary steam engine into a practical working machine made a long step toward revolutionizing the conditions, allowing power to be furnished and mills to be located at the dictate of general considerations of supply and demand.

Machinery was also imperatively required. To have a good supply of this, at moderate prices, machine tools must be had for making it. These tools, various, convenient and effective as they now are, consist mainly or largely of outgrowths and applications of the principle of the slide rest. Even in those machines which involve other features of immense value, like the steam hammer, the modern grinding machine, etc., the principle of the slide rest is an indispensable part of the combination.

Simple and obvious as this device appears, it is one of the most important factors in modern industrial progress. If any one wishes to get a just idea of the radical difference between the old and new ways and the sharpness of the transition, let him reflect upon the fact that the slide rest was not known by machinists generally till 1794, and was reinvented in that year and put to practical work in connection with the turning lathe; and, further, that notwithstanding its immense efficiency as a labor-saver and talk excitant, it was not utilized in the building of a metal planer, even for flat surfaces, till 1825. It is stated that the introduction of such machines immediately reduced the cost of producing plane surfaces to less than one per cent. of the cost of equal work by chipping and filing.

In the meantime, many fairly efficient machines had been devised and brought into use in the textile and other industries, so that the mill system of manufacturing was then fairly started.

But the more it grew, the more urgent became the need of better means of transportation. The problem of steam transportation by water proved comparatively easy. But it was much less easy to hit upon the proper combinations for success on land, viz., the abandonment of common road surfaces and the substitution of metallic rails, very radical reductions of the limits of gradients and curvatures, the use of high-pressure steam, multitubular boilers and the exhaust blast.

This combination having been completed in 1829, the great essentials for the development of the mill system were ready, viz., the steam engine in good working efficiency, a fairly good supply of irons, machine tools and general machine-making and steam transportation, all well started.

I understand that a gentleman for whom we all have a high respect, in a recent address to an assemblage of Boston merchants, claimed that these great movements were caused by the development of the banking system. But long before this was said, a parable was invented to answer it, viz., the story of the two Yankees who were thrown upon an uninhabited island in a condition closely approaching to destitution, but in a few days each became rich by trading jack-knives back and forth with the other. This champion lie has a poetical thoroughness and vividness which the other statement lacks, but both involve substantially the same absurdity. Many things were indispensable in these improvements without being in any fair sense the cause of them—paper, for instance.

The development of the mill system has been a powerful stimulant to the improvement of water wheels, or, perhaps, we may say that the latter has been a part of the former.

In the infancy of this country, when there was a superabundance of land and great reverence for the authority of the State, it was easy for the government to exercise the right of eminent domain. Later on, the "fierce Democracie," forgetting that their titles originally issued from the State, subject to this right, in all its breadth, contested its exercise for any purpose excepting the laying out of highways. But in the time of Queen Anne it was easy to see the justice and wisdom of using it in aid of mill building, to the extent of authorizing any riparian owner to build a dam on his own land and maintain a head of water for actuating a mill—though it might incidentally flow back over land of owners above—on payment of proper damages, ascertainable by legal proceedings. Neither natural right nor the public interest can be pleaded in favor of allowing an owner of farming lands to also hold waterfalls running to waste through them, when other persons wish to put them to useful work for the general benefit.

In this early time, the practical necessity for such aid to mill building was much greater than it is now. The steam engine was not in sight in the future. In Massachusetts the main bulk of the population was spread out to an average of perhaps not more than 20 persons to a square mile, so that the number of people within reach of any mill—by the bad roads then in existence—was not sufficient to promise it much business; and capitalists with a few hundred dollars to invest in building and operating mills were not numerous.

Considering the urgent need for grist-mills and saw-mills, and the unquestioned right of eminent domain, the Legislature of the Province of

Massachusetts, early in the eighteenth century, made a law—commonly called the mill act—authorizing flowage under the conditions above stated.

Through all the changes of our statutes, this provision has ever since been, and now is, a part of the law of Massachusetts, and it has also long been a part of the law of many other States.

But the right was not restricted to grist-mills and saw-mills. In the course of time other industries, in iron, paper, gunpowder, wool, cotton, etc., started and began to use water-power, also in a small way, here as well as in other civilized countries. Establishments for these industries were also styled mills, *i. e.*, assemblages of inanimate machinery and motors for performing certain mechanical operations: and so far as I know, the point has never been raised against any such establishment that it was not a *mill* within the meaning of the mill act, and no attempt has ever been made to exclude any of them when the general statutes have been revised from time to time.

Thus a cotton mill, a watch factory, a machine shop, or an electric light plant, can, without question, exercise the flowage right originally granted in aid of the grinding of food materials. Rightly and wisely so, in my opinion. The cases in which injuries by flowage cannot be or are not entirely compensated for by money damages are very rare. Doubtless there are many general laws which involve much greater individual hardship than this. Moreover, the broad and statesmanlike view seems to be that these later industries are as needful to the strength and prosperity of a great country as the little rude grain-mills and saw-mills were to the immediate wants of a poor agricultural one.

In the development of the mill system in Great Britain, with no considerable water powers, and with a good supply of coal, steam was the only source of power to be considered. In New England the conditions were reversed.

The little beginnings of the bituminous coal business in Maryland were merely local, and not suspected of having any relation to affairs in New England. Anthracite, as a practically useful fuel, was unknown. Here there were many excellent water powers running to waste near tidewater. Probably no one thought to ask whether there was any other source of power practically available, and if the question had been raised every one would have said, without hesitation, that steam power was wholly out of the question by reason of its much greater cost. Whether the existence of these water powers suggested the building of mills on a large scale, or the desire to build such mills called attention to the water powers, it is evident that without the latter the mill system would not have grown up here when it did.

It is easy to see why Lowell should have been selected as the place for manufacturing on a large scale, by the Boston promoters, after the success of their first start at Waltham. For the first few years the water power easily available at Lowell was in excess of the demand. But most of the people seeking for mill sites naturally went there in preference to making large expenditures for land, dams, canals, grading and other matters needful for developing water-power in other locations.

Thus it happened that the sagacious men who controlled the business in Lowell learned by the most certain test of experience that their water

power was very valuable, and looking ahead, they clearly saw that the demand would soon exceed the supply. The conditions were favorable for the development of the genius which would produce a more efficient and convenient water-wheel. The man was already there in the person of Uriah A. Boyden, then or recently engaged in the engineering works of the proprietors of the water-power.

The high-breast wheels used there prior to 1840 were as good as any, and much better than most, of the wheels in general use. A few turbines had been made in France and in this country which gave a maximum utilization of 76 per cent. of the water-power expended. The best breast wheels of ample size for the water applied could do about as well, but in practical work they probably gave not more than 55 to 67 per cent., depending largely upon how much water was crowded on to them.

Boyden began soon after 1840 about where Fourneyron left off, and soon ran the utilization up to about 88 per cent. Becoming intensely interested in this work, he continued perfecting the theory, with the aid of careful tests of about 20 turbines of his construction, under falls varying from 7 to 35 feet, until he obtained a utilization of about 95 per cent. His tests were, of course, made with weir measures of the water used and friction brake dynamometer determinations of the power yielded.

Subsequent observations of a less exact nature tend to corroborate this result. The careful experiments of Boyden and others enable us to estimate from the dimensions of a turbine of this type how much water it will use under given conditions, with a close approach to exactness. And good estimates of the power obtained can often be made by alternating the turbine with a steam engine in actuating the same machinery, measuring the whole power and also that absorbed in the engine itself, by indicator cards, and subtracting the latter from the former. In a comparison of this kind which I recently made for a turbine of about 740 horse-powers under 40 feet fall, it seemed most probable that fully 95 per cent. was utilized.

Since 1850 many ingenious men have spent much time and thought for improving turbines in other directions. One desideratum has been cheapness of first cost. Many buyers give too much weight to this. In general it involves putting a large quantity of water through a wheel of relatively small diameter, with more or less lowering of the ratio of utilization. But in many places where water is constantly running to waste, and likely to do so for many years to come, common sense calls for cheap but durable turbines without much regard to economy of water.

Another and more important desideratum has been to make turbines which will give high ratios of utilization with the gates partly closed. The most favored way of securing this result is by the use of wheels combining inward and downward discharge. This requires a complicated form of bucket, and the theory of the motions and pressures of the water is too abstruse for anything like complete mathematical analysis. Nevertheless, intuitive judgment and patient experimenting have produced several good wheels of this type, whose ratios of useful effect fall off but slowly with diminution of gate opening.

So far as I know, very little improvement in hydraulic motors has originated in Europe during the last fifty years—nothing worthy to be men-

tioned even, in comparison with what has been done here. Our progress in other branches of hydraulics also compares favorably with all that has been made elsewhere in the same time, notwithstanding the fact that foreign investigators have had large amounts of public money for making extensive experiments.

A few years ago, A. De la Candolle elaborated, at great length, the theory that the best test for gauging the intellects of the different nations is to ascertain how many individuals per million of them have been members of the different learned societies in Europe.

The inadequacy and injustice of this theory, *as applied to the people of this country*, is strikingly apparent when we consider how much more progress we have made in the last sixty years in the theory and practice of hydraulics than all the rest of mankind. Yet our principal workers in this line have not been members of any foreign society: they have not run to Europe for recognition. The learned De la Candolle is probably almost wholly ignorant of their existence and their works.

While the improvements in hydraulic motors developed by or with the mill system of manufacturing, since the time of Fourneyron, have been substantially limited to this country, our contributions to progress in steam engineering, automatic tools, electrical work and various other matters, will compare favorably with those of all the rest of the world, and have attracted much more attention than our hydraulic work, they have gained few if any elections to membership in foreign learned societies.

In this gauging of intellects it must be remembered that America is, to a large extent, a world by itself: that our workers are tolerably well content with the substance of progress and acquirement, and have not much time or inclination to struggle for European appreciation; if it comes it is a pleasant incident merely, but it cannot make our discoveries and improvements any more certain—ignorance of them cannot make them a particle less certain.

It is obvious that many parts of the work of planning and building mills are substantially similar to operations in other branches of engineering. Our subject limits us mainly to points which are peculiar to or specially prominent in mill engineering. It cuts us off from the discussion of many matters of the first importance with which all engineers are acquainted, but leaves us a multitude of secondary of minor points which may have some novelty and interest for workers in other branches of the profession.

One advantage which the mill engineer has, pre-eminently, is that he has numerous opportunities to observe the results of many risky experiments tried by men whose knowledge, prudence and judgment vary greatly. Much can be learned from such observations, but it is not wise to generalize very dogmatically from a single failure—much less from a single escape from failure.

To begin at the bottom—it often becomes necessary to build high mills and heavy storehouses over arched water-ways much larger than ordinary conduits or sewers. Many of these water-ways, 10 to 16 feet wide, are built with wooden floors, sometimes sub-filled with concrete, brick side walls 16 to 24 inches thick and 4 to 6 feet high, and brick arches rising

one-fifth to one-half the span, 12 or 16 inches thick. It is obvious that the thrust of these arches must be resisted mainly by the earth back of the walls (which is filled in, of course, before the centres are struck). This seems rather risky, but I do not remember any instance of failure or serious crippling in such a case. These arches are usually loaded with 5 to 20 feet of earth, and sometimes piers to carry 20 tons each are built upon them, wherever they chance to come. In good practice the arches are thickened at such places.

Single race-ways often take the water from two or three turbines, say 250 to 400 c. f. s.; in which cases they are likely to be from 20 to 25 feet wide and 5 to 8 feet deep, with side walls of rubble stone laid in cement mortar and brick arches of about one-fifth rise and 16 inches thick. Where mill columns come over such arches, it seems to me best to support them by trusses, independently of the arches.

Many mills are built on the banks of rivers, from which it follows, not unfrequently, that one wall stands on good hard bottom and the opposite one on piles. At the points of change we are likely to have a deep foundation wall on earth bottom, adjoining very short piles in soft material, and to feel some anxiety as to unequal settlement and possible cracking of the superstructure. But in the few cases which have come under my own notice I have not observed any such results.

In many cases the bottom on the river side is softer than on the other side. It may not need piles, but only a wider earth base in the foundation walls. I have seen a few very old mills which were still settling and cracking from insufficient earth base on the softer parts of the sites; but I think these cases of long-continued settlement are rare.

In the very common case of the up-hill side of a mill standing on a bank wall with a surcharge of 5 to 20 feet of earth on the outside, these walls often yield slowly to the relentless pressure. For several months in every year a thick stratum of earth is powerfully expanded against them by freezing. When the earth thaws, it follows up any yielding which has occurred, and the process is repeated in every succeeding winter and summer.

An accumulation of a few inches of such movements in twenty to fifty years, which might not be specially noticeable or objectionable in a mere retaining wall, will seriously distort a mill—especially an old-fashioned, narrow and high one—throwing some of the walls out of plumb and straining their connections with the others; also throwing columns out and bringing the weights on to them diagonally instead of axially, and endangering the stability of small pintles at the floor beams, if such are used. Many and probably most old mills with unbalanced earth pressure on one side have been considerably distorted in this way. The modern practice of building such bank walls with cement mortar and draining the earth behind them will doubtless contribute materially to their stability.

The large dimensions of modern mills raise into importance certain considerations, which are often ignored with impunity in the case of buildings cut up into rooms of smaller sizes.

One of these is that an unbroken floor of 3-inch plank, four or five hundred feet long, will change its length as well as its width, with changes in the amount of moisture which it contains. I have known a tightly-fitted

lower floor of well-dried plank, to expand lengthwise enough to push the end wall of a mill out and crack the side wall at the first window from the corner, with no settling, or any change except mere horizontal separation. The end wall was well fastened to the floors above, and as these did not gain moisture there was no crack anywhere above the first-story window.

On the other hand, I recently examined a mill nearly 500 feet long, which was floored throughout with planks just from the log. In drying, all the floors above the first story shrunk from 4 to 6 inches in the whole length, and as they were not well fastened to the end walls, after bending these walls in an inch or two, they pulled away from them, leaving a gap of an inch or more at each end. Of course, the floor beams were also moved toward the middle of the length of the mill and carried the columns along with them. Probably the ground floor shrunk but little, leaving the bottoms of the first-story columns about in place, so that they were *canted* out of vertical, perhaps 2 inches at the ends of the mill, and diminishing from that to nothing at the middle. They were about 16 diameters long, so that an inclination of 2 inches would throw their end planes $\frac{1}{8}$ inch out of level, leaving only small areas in bearing, with crushing pressures at the salient edges, and bending the axes of the columns into reversed curves.

If the columns had been made of cast iron instead of wood, the diminution of end surface in bearing and the resulting concentration of pressure would have been vastly greater, owing to the rigidity of the material.

If the ends of a column are not plane and square with the axis, or if the surfaces against which they bear are not plane and level, the same mislocations of the pressures occur, and the column suffers still more by being bent wholly to one side instead of into reversed curves on opposite sides of the line of pressure.

It is evident that the consequences are the same when such mislocations of pressure are caused by poor work in the original construction, as well as by any subsequent movement. Probably there are many cases where bearing surfaces, say nine inches in diameter, are open $\frac{1}{32}$ in. at one edge, which may be caused by setting a post $\frac{1}{2}$ in. out of plumb, or by other poor work. This is too much for wooden columns, far too much for iron ones.

It seems rather probable that these poor fits materially lessen the resistance to horizontal vibrations of floors, which is often troublesome in mills where looms are beating.

It is common to cast the bearing plates with rims around them, forming sockets to receive the ends of the columns. These sockets effectually conceal the worst possible fits between column and plate, as made by the most careless builders, and also prevent the most careful ones from seeing whether the fits are good at first and whether they remain so. Such sockets at the lower ends of columns hold all the water that happens to reach them, and are thus very efficient in rotting the wood. I have traced rotton cavities made in this way several inches up from the base.

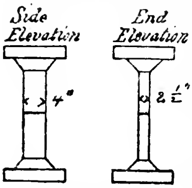
The ostensible reason for making these sockets is to hold the columns in place. But, ordinarily, a central projection, cast on the plate, say $1\frac{1}{2}$ to 2 in. in diameter and 1 in. long, fitting into an axial hole at the end of

the column, gives security enough. If the column is bored for ventilation the hole is already there.

One of the worst *fumbles* ever made in mill construction is in the matter of pintles for carrying the weight from a column down through floor beams to the column below, or between loose plates at the ends of such columns. These have often been made of iron cylinders about 4 inches in diameter and with rough ends. The ill-fated Pemberton mill *teetered* out its brief life on props of this kind.

A large building was recently erected near here with oak blocks 5 inches square, trying to act as pintles on cast-iron columns 9 inches in diameter and 1⅝ inch thick.

A high and very heavily loaded building stood for several years, near here, with T shaped pintles having stems 2½ × 4 inches butting together in mortises through the floor beams, and each carrying loads of from 200,000 to 300,000 pounds. As it is practically certain that in many cases the ends offset, more or less, at the place of meeting, and that many of them were *canted* so that their end planes were not in the same plane, the wonder is that very few of them failed, and the building continued to stand till it was re-enforced.

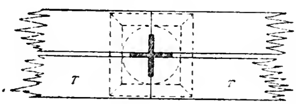


The method of cutting the beams short, and carrying the column down to a plate resting on the column below, which is long and strong enough to carry the beam ends also, is much safer when properly arranged, and answers well for storehouses.

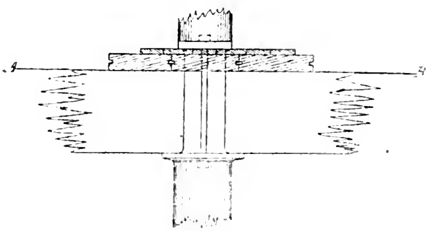
But for a good class of mill-work suitable pintles are much better.

A very little consideration will show that the end plates and the connecting part between them ought to be cast in one piece. The connecting part, or stem, is best made of cruciform cross section:* and it should

Section on AB.



ELEVATION,
with front beams T T removed.



extend up to the top of the floor, carrying its top plate just above this level; so that the column above is favored as to dry rot, and is above water

* Obviously, this is not the best form for economy of iron, but the difference in cost is unimportant.

when the floor is washed, and it also has the advantage of leaving the joint in sight. This requires a central boss on top for holding the upper column in place, as well as one below for the lower column. In extra wet places, like dye-houses, it is a good plan to carry the top several inches above the floor.

Finally, the castings should be centred on the ends of these bosses, put into a lathe and the bearing ends turned off square with the axis.

I began to use pintles of this kind nearly twenty years ago, and have used thousands of them with entire satisfaction. They fulfill all the requirements perfectly, and there is no good excuse for not using pintles of this general type in all ordinary cases, or for using small prisms separate from the end plates, in any case.

Many carpenters like to fit floors in very closely, especially top flooring boards. Sometimes these are cut long and sprung in with the well-known action like that of a toggle-joint, so tightly that the ends of the boards are very noticeably *upset* against the irregularities of brickwork. This, of course, means a pressure of several tons per board. By accumulating pressure from several boards in this way, it is easy to bulge out a wall or to pull it apart longitudinally, making a crack from a window above to one below the floor which exerts the pressure, especially in the upper stories, where the walls are thinner and weaker than nearer the ground.

The non-expert public usually charges such cracks, as well as most others, to defective foundations, even when they appear far above the ground, and with no other rupture above or below them; in which case a very little reflection ought to show the absurdity of this notion.

This results largely from the intuitive feeling which most people seem to have that brick or stone walls will stand almost any amount of pressure, either compressive, tensile, bending or detrusive; partly also from the difficulty of realizing the meaning of words or figures representing very large forces. When represented by the gravitation of visible masses of matter like stone or iron, they affect the mind for something nearer their real value. People who are accustomed to move such masses, up to five or ten tons weight, are likely to have a fairly good conception of their magnitudes; but if they are not familiar with larger weights, either by moving them or trying to appreciate them mentally, all beyond that is merely indefinitely large: it makes but little difference in their minds whether you say 20, 50 or 100 tons.

Many mills for textiles are now made 100 or 125 feet wide, and in good practice they are well supplied with natural light—better than many narrow mills, in the building of which the importance of this matter has often been strangely overlooked.

Light from combustion is comparatively poor and costly. Where much of it is used for several hours in succession, as in large and poorly windowed weaving-rooms, for instance, the vitiation and overheating of the air sometimes approach closely to the point where operatives of ordinary stamina can barely exist but have no vigor left for work. Doubtless their ability for work the next day is also lowered by this; often also by the colds taken on going out.

The superiority of electric lights in this respect is one of their great advantages.

To secure good natural light in a wide mill, the stories must be high and the windows large, occupying 40 per cent. or more of the side-walls, and leaving but little width of brickwork between them. Just above these tall and narrow masses of brickwork carrying the whole weight there must be large cavities in the walls to receive the beam ends. These conditions call for well-built walls of good thickness. As ordinarily made, such walls settle together considerably, and this must be taken into account if one wishes his upper floors (supported partly on the walls and partly on columns) to remain closely level. Window sills are also more likely to be cracked, but this can be wholly avoided, of course, by proper precautions. If window frames are built in tightly the pressure forces the stools down at the ends and leaves them bent up in the middle.

Perhaps a few words ought to be said here on the controversy between high and low mills. All must admit that the objections to heights of six stories or more are of considerable importance, though diminished by having a good number of stairways, well located, and by automatic sprinklers, etc. As we are all aware, the case for one-story mills has been urged with the greatest vigor and ability here in Boston; but, probably, the great majority of manufacturers think the relative merits, as a whole, of this style of mill have been overestimated, and do not believe that the balance of advantages generally rests with it. But however this may be, the agitation for some reduction from the old extreme heights is a good and useful one. In practice, however, the decision as to the number of stories must often depend largely upon the exigencies of the location, the character of the business done, and other special circumstances.

One of the most satisfactory reforms ever introduced in the construction of mill buildings was the getting rid of all hollow spaces surrounded by woodwork. This improvement was begun 50 years ago or more by throwing out the old-fashioned floor joists with lath and plaster under them and substituting the solid floors now in general use: and it was advanced a long step further about 35 years ago by dispensing with steep-pitched roofs and substituting flat ones covered with felt, pitch and gravel. These steep-pitched roofs made bad fire risks, at the best—very bad as ordinarily finished—and they were objectionable in other respects. At first the flat roofs were made with one-inch boards, requiring supports by joists not over two feet apart. A few years later, planks and beams were substituted, making the construction substantially like that of the floors, excepting the slight slope required. I understand that a member of this society designed roofs of this kind over 30 years ago, and began to build them in 1861 or 1862. It seems that the same idea occurred to others independently at about the same time. Like many other good things, it seems simple and obvious enough now; but no one acquainted with the subject can compare the steep roof and the flat one without a feeling of satisfaction amounting to positive pleasure at the superiority and fitness of the latter, in every respect.

The works inside of the building, however, are the main substance of the mill, and require the principal care and thought.

When we come to consider these we find that modern mills, especially for some kinds of textile fabrics, have become very complicated, and the

tendency in manufacturing generally is toward greater complexity. Sometimes a new improvement simplifies a machine or process, but more often it brings in some new organ, machine or apparatus to do the work better or to do something which was previously neglected or trusted to manual labor.

To get all the different works co-ordinated in the best way, free from mutual interferences and needless complexities, it is desirable that substantially everything should be planned before anything is built, though some small matters, like details of gas-piping, wiring for electric lights, etc., may be left to take their chances: they must keep out of the way of other things in any case.

Some ingenuity and much patient study are needed on the part of the designer to get plans thus well matured in advance of construction. Time is also needed, and owners are often unable or unwilling to allow this. It requires less mental effort to take one step at a time and trust to luck for the succeeding ones—to put up shafting and belts, and then consider how to arrange the various systems of piping, etc. But in doing this, one will always find some of the previous constructions which he wishes were different and which might have been varied as well as not if the requirements of the later work had been seasonably brought out by planning all at the same time.

Of course, the planning should begin at the right end: first, the determination of the product required, and the schedule of machines to make it; then the placing of these machines in convenient relations to each other, and so as to use floor space to advantage, leaving only so much as is needed for passageways, stock in process, etc.

Along with this must be considered the dimensions of building and number of stories required to furnish the needed floor space conveniently and without breaking departments; also, the nature of the power plant, the location of the rooms relative to it, the spaces required for main belts, etc.

Other things being equal, it is desirable to have the water-wheels within the mill, so that the power may be carried from a first horizontal shaft of moderate length directly to the main shafts in the different rooms. The same principle applies in the case of steam engines: but when their fly-wheels are too large to go inside conveniently, they may be placed just outside and still have the advantage of belting directly to the principal main shafts.

It is obviously desirable to have the boilers in a one-story building at a moderate distance from the mill, and in any case, to have ample space, say, seven feet high above them, for pipes, light, inspection and repairs.

It is well to have a large number of main shafts driven directly from the fly-wheel or main drum. This saves dividing up of power further on by other transmissions through large counter belts, which are always objectionable over the machinery. Many small ones must be used, however, and it is important to locate them where they will do the least harm. It is a good rule never to run pipes through them, with the risk of their being pulled down and broken by the belt in case of accident, allowing escape of steam, gas or water.

If sprinklers are to be used, their locations should be considered, and reasonable concessions should be made to keep the shafting and belts

clear of them, and, as well as may be, of the pipes for supplying them. The same is true of steam pipes for heating and of atomizers for moistening the air and the pipes for supplying them, if these are required.

Formerly it was the general custom to heat by pipes running along the walls under the windows. This would seem to be the best position for taking care of the cold air coming down from the walls and windows. But pipes here take up about four inches of space, ordinarily one per cent. of the whole floor area. Inflammable stock, lint, waste, etc., are also likely to come in contact with them, increasing the risk of fire. These objections can be avoided, in part at least, by placing the pipes overhead, where, if they are near the walls, they heat the rooms well enough. Usually the top of a room is less crowded with shafts and belts near the walls than toward the middle.

Within the last few years the system of indirect heating with steam coils and blowers has been coming into use and has given good satisfaction.

Other things being equal, it is desirable to have a shaft run along the middle of the space which it serves with power, so that the counter-belts can balance each other in their pulls upon it.

All counter and machine belts less than about six inches wide should have room enough to run off or be thrown off, on one side at least, without fouling, and it is well to have positive stops to prevent their running off the dangerous side, if there is one. I have seen plans made for four or five machine belts to run in close proximity to each other on one wide pulley—a very unprofitable and dangerous thing to try.

A competent designer who knows that such arrangements are inadmissible will not get get caught in them; but he will often find good reasons for going back and changing his previous drafts, moving shafts sidewise and also altering their make-up, in favor of other things. Sometimes the modifications will run back even to the arrangements of the machinery and of the building.

The most difficult cases arise in connection with alterations and enlargements of existing plants. In these cases, especially, it is often difficult to decide between several alternative schemes, all having some unsatisfactory features. If the designer is a conscientious and painstaking worker he will develop these schemes, and perhaps some others which are thought of during the process, far enough so that whoever is to decide between them can clearly see their respective merits and defects.

In planning transmissions of power, it is important to consider where the minimum of costs occurs, as between pulleys and belts. The larger the pulleys are the more they will cost, but the faster the belt will run and the less will be its width and cost, at first and also for renewal. It will also make less pull and friction on the shafts, develop less dirt and electricity, and can be more easily thrown on and off. Many manufacturers and mechanics never even think of these things and would be greatly surprised to know how much money they have wasted and how much inconvenience they submit to in using wide belts at low speeds.

Due regard to these considerations will usually fix the diameters of counter-pulleys at 30 inches and upward. With such diameters the advantages of using double-thick belting ordinarily exceed the disadvantages

and this halves the widths, saving space, which is often important, and looking neater, in any case.

It is desirable that all the piping, shafting, pulleys and belts, and especially these running parts, should not only barely clear their surroundings, but should have ample space around them, for convenience of erection, care, repairs, etc. Failure in this respect is fatal to anything like elegance of design.

If everything is well arranged the mill will look much simpler and the designer will receive less credit than if he had thrown it together at hap-hazard with more shafts and counter-belts, more complicated piping and more crowding generally.

Much the most common practice in designing shafting is to depend for its support wholly upon hangers on the floor beams or columns, usually 8 feet apart or more: then the best that can be done is to locate the larger pulleys for main and counter belts close to a hanger on one side, hence 5 or 6 feet from the one on the other side. This throws too much of the strain on to the near hanger, and moreover the head length of shaft, which carries the main pulley, has to be made much larger than is needful for any other reason, merely to avoid excessive bending. Very often the same is true to a greater or less extent of the rest of the shaft. Very often, also, the increase of size to secure stiffness is insufficient, so that too much bending occurs and wastes much power without attracting attention.

Some 20 years ago certain wide-awake manufacturers made a new departure in the direction of using very small shafts at high speeds. This was pushed to an extreme, which required many intermediate hangers—perhaps one in every bay, on an average—and was troublesome in other respects.

As to the main pulleys, it is much better, and little if any more costly, to locate them wherever they are wanted—anywhere in any bay—then put in special timbers so as to have a hanger close to the pulley on each side and each equally well supported.

As to the rest of the shaft, the best modern practice steers between the two above-mentioned extremes; fixing minimum diameters by the rule that a shaft must be stiff enough to carry the great majority of its pulleys and belts without intermediate hangers, and then putting in the latter wherever they are needed to take good care of all the wider ones and of assemblages of narrow ones in any one bay.

In comparing such a system with one requiring intermediate hangers throughout, we shall find no important difference in cost or in power required, but the former will be simpler, more elegant and more convenient. It will be better than a system having no intermediate hangers in every respect.

Special timbers for carrying hangers and other things which ought to remain strictly in place are often injudiciously made to depend upon clamp connections only; *i. e.*, they are merely bolted flat against their supports, so that shrinkage, jarring, belt pull, etc., are sure to result in displacement. This should always be prevented by shoulders or positive stops of some kind.

The speeds of shafts are limited mainly by these considerations:

a. It is desirable to have them fast enough to transmit all the power required with the smallest practicable diameters. Also to have the pulleys

which drive the machines as small as may be without having any of them too small; *i. e.*, to get the proper belt speeds with small, quick-running pulleys, which are cheaper and less in the way than larger ones.

b. The speed is limited in the other direction, not only by the condition that none of the pulleys shall be too small, but also by the fact that it is unwise to incur unnecessary friction, etc., by running faster than needful: also by the obvious inconveniences and dangers of running ordinary shafting and pulleys faster than about 500 revolutions per minute.

Much has been said lately, with some show of probability, as to the impending transfer of a large share of our New England manufacturing business, and especially in the heavier and coarser lines, to the South and West. Whether this movement is to be more or less rapid and general, it seems that our best policy here is to turn an increasingly large part of our attention to the production of fine and high-priced goods, the business of making which cannot be so easily learned and started by beginners elsewhere.

The principal requisites for this are capital, of which we have plenty; energy, in which we are not deficient; and skill, which is most important of all. We have considerable of this already developed, and perhaps an unrivaled capacity for acquiring more by trying.

This skill is needed not only at the head, but down through the ranks of the operatives. Bad conditions do not develop, attract nor hold good operatives; instead of this they give a procession of indifferent ones; sometimes there are not enough of them to keep all the machinery going, and at other times the pay rolls are loaded with too many spare ones, in anticipation of such a scarcity.

Some of the good conditions which are profitable to have everywhere, and are especially needful in making fine and high-priced products, are as follows:

1. Good light, temperature and ventilation. In many places some or all of these desiderata are lost or thrown away with scarcely any saving of cost or other advantage, without thought or question.

2. The different departments should be well balanced, so that none may be overstrong and costly for the amount of work required from it.

3. Every shaft should make its appointed number of revolutions, with clocklike regularity, through every second of running time.

All these things depend largely upon the design and construction of the mill, partly also upon the management.

4. The overseers and sub-overseers must do their work well and promptly, so that no machine will wait for attention longer than is positively unavoidable.

5. To make sure that these possibilities are made actualities, that no machines shall wait unnecessarily for power, material or overseer's attention, a live manager is usually needed. In many cases he will find it essential to have a good and minute system of accounts and reports, so that he may keep watch not only of his total weekly products, but also of the details by machines.

6. If these things are well attended to, the principal condition for keeping good operatives will be fulfilled; viz., they will have opportunity and incentive to do full work and will be able to make good

products in large quantities; hence to earn good pay at moderate rates per pound.

This brings us to the end of our story. These are the results for which mills are built; the making of good products in large quantities at moderate cost is the prime condition of success.

DISCUSSION.

BY MR. JOHN R. FREEMAN.

The percentage of useful effect developed by the Boyden turbine stated in the valuable and interesting paper to which we have just listened, is so very remarkable that it would add much to the interest if Mr. Sawyer would kindly give us the authority for the efficiency of 95 per cent. which he quotes as attained by Mr. Boyden.

Mr. James B. Francis, whose knowledge, skill and experience in these matters is, I think we will all cheerfully grant, not excelled by that of any man living, in his "Rules for Proportioning Turbines," published in the Lowell Hydraulic Experiments in 1855, and based upon a study of several of Boyden's best works as well as upon his own experiments, assumed 75 per cent. as a fair average value for the efficiency; this being intended, probably, as a conservative estimate which could be relied upon as a result of care in design.

The very greatest efficiency attained in any one experiment upon Mr. Francis' Tremont turbine, built in 1851, and designed in the light of a full knowledge of the details of some of Mr. Boyden's best works, was 79.4 per cent.; this being a test by Mr. Francis where all the conditions for the highest degree of accuracy were fulfilled, and with the computation of water discharged based upon the Francis weir formula as established at a somewhat later date.

The highest turbine efficiency mentioned in the Lowell Hydraulic Experiments is that for Mr. U. A. Boyden's "Appleton Turbines," which, in a test where Mr. Francis was, I understand, responsible for only the computations and not the observations,* developed an efficiency of 88 per cent., and was paid for on this basis. From general descriptions I have inferred that this 88 per cent. wheel was one of Boyden's masterpieces, and contained, I think, substantially all the devices that he ever applied to a turbine for bringing out its utmost percentage of useful effect at full gate, and was built almost regardless of expense. Of this 88 per cent. three per cent. was due to the use of the diffuser, a device not applied to the Tremont turbine.

As this Appleton turbine was built some five or six years previous to

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* It is not intended to cast the slightest intimation that the observations were taken with any other than a view to give, most impartially, the exact truth. These words happened to be prompted by the same feeling, which is more clearly expressed in the next paragraph; namely, that this was in the very early dawn of extremely accurate measurement of very large currents of water, and that perhaps the conditions surrounding the measurement might have been just enough different from those which attended the standard weir measurements made by Mr. Francis himself a few years later to account for, say, two or three per cent. of this very high record.

I have always been taught to feel that Mr. Boyden was an earnest and honest investigator, who published very little and whose clear, deep insight into these hydraulic principles has never been appreciated, except by the very few who were brought into immediate contact with him.

the well-known weir experiments, I have sometimes wondered if the data for the exact computation of the discharge was not less perfect than for the Tremont, or if perhaps the conditions necessary for great accuracy in weir measurement were not then less perfectly understood. This is a mere notion, however, for I have no information on this point other than the printed statement above referred to, but have thought perhaps this might account for some portion of the 5.6 per cent. superiority of the Appleton over the Tremont after allowing for the diffuser.

The only tests I can recall of a Boyden wheel with which the figures 96 per cent. are in any way connected are those of the Atlantic Mills turbines at Lawrence. These were constructed under a contract giving a generous premium for each one per cent. above 76 which might be obtained, and were designed and built within about a year of the Appleton turbines above mentioned, but did not contain the feature of spiral approach of water, which was considered to add to the efficiency of the Appleton turbine. Thus these wheels also were constructed five years prior to the establishment of a reliable weir formula.

I remember to have heard it said that in the somewhat celebrated lawsuit for compelling payment of the very large premium claimed, Mr. Boyden's lawyers claimed 96 per cent. efficiency, and attempted to prove it by ponderous mathematical deductions, but other evidence was put in tending to show an efficiency of about 86 per cent., and final settlement was made, I believe, on the basis of an efficiency about the same as that for the Appleton turbine already mentioned.

As to high percentages obtained from other than Boyden turbines, some of the tests in the old flume at Holyoke indicated a phenomenally high efficiency, but if I mistake not, the conditions of approach of water to weir was such as to warrant the use of a little margin with these figures.

These weir measurements on which tests of efficiency always rest, if to be certain within two per cent. or even five per cent., is not such a simple matter as is sometimes supposed. I have heard of phenomenally high results, which were explained by discovering that depth was measured too near crest of weir, or again, improper shape of approaching channel or irregularities of velocity of approach may readily introduce errors of two per cent. or more, and an acquaintance who had probably had more done than any other turbine builder of the present time in the way of experiment and testing for the development of a high class turbine, once told me that when a test on any wheel showed more than 85 per cent. he felt as he did when twice two made five—that there was something out somewhere—and that so far he had invariably found it.

Prof. Unwin published a paper a few years since in which, as I remember it, he took the ground that 80 per cent. of useful effect was about as much as had ever been really obtained from a turbine. In reaching this conclusion he was influenced by some theoretical considerations of the necessary friction losses. Had Prof. Unwin been fully conversant with certain of the results obtained at different times and places by Mr. Francis, Mr. Mills and Mr. Herschel, he would, I think, have been forced to raise his figure a little.

In my ten years' connection with the water power company at Lawrence, and in considerable professional experience with turbines elsewhere,

I had occasion to study all sources of reliable information on these points that were available to me, and certainly never found thoroughly reliable evidence of an efficiency much above 85 per cent. for any kind of water wheel. Hence my interest to learn more about the tests referred to by Mr. Sawyer, running so much higher.

It is to be kept in mind that in all these tests these high figures are exclusive of friction losses in penstock, tail race and in the gears or belts connected to the wheel when in use.

To return to the Boyden turbine, I think we may say almost every such wheel built in the United States other than from the direct designs of Mr. Boyden and Mr. Francis has been based either on main strength and guesswork or else upon Mr. Francis' rules, and I cannot recall any thoroughly reliable tests of such a wheel indicating that Mr. Francis' results had since been improved upon. It is of course entirely possible there have been such tests, and my purpose in rising in this discussion was to gain such information, for from what I could learn heretofore, I have been inclined to consider that the 79.4 per cent. of the Tremont turbine plus the 3 per cent. which would have been gained had a diffuser been added, may be fairly taken as the best efficiency thus far obtained with positive certainty from this type of wheel. But the 88 per cent. of the Appleton should also be kept in mind as a possibility.

Taking all the best information at hand as to results of previous tests and as to inevitable losses from friction and eddies, if, as stated by Mr. Sawyer, a recent test of a Boyden wheel has shown 96 per cent. efficiency as a deduction from experimental comparison with the indicated power of a steam engine doing the same work, then are there not the best of grounds for feeling that some part of his experimental data or deductions in this rather uncertain method of test must have been about 10 per cent. in error?

BY MR. EDWARD SAWYER.

Mr. Freeman has raised some important questions which deserve fuller discussion than time and space now permit.

The Tremont turbine was actuated by a small fall—about 13 feet—and it should be remembered that the inevitable losses are relatively larger for low than for high falls.

By referring to the "Lowell Hydraulic Experiments," it will be seen that the lines of its guides and floats were made up of circular arcs, drawn by rules which do not profess to give the best forms, but only such approximations as can be readily followed by any mechanical draftsman. In these forms and in some other important respects the Tremont turbine differed considerably from Boyden's perfected practice. The principal object, as I understand, was to formulate simple rules for designing turbines as well as may be, consistently with the desired simplicity. The undertaking was a useful one and made with the author's accustomed skill and thoroughness; but the test seems to me to show that the variations from the best practice were too great to allow a very good result. There is no material saving in cost of construction—assuming equally close adherence to the designs in both cases: and in the light of present knowl-

edge, I conclude that it is profitable to pay the slight additional cost of procuring the best designs attainable.

Boyden's guides and floats had constantly changing curvatures—the object being to introduce the water to the wheel without abrupt change of direction or velocity—hence without shock or much pressure; then to steadily increase the pressure of the water on the float, to a maximum, towards the outer part of the wheel, and from this to run down steadily to about zero pressure again at the outlets—exhausting the water of all its *vis viva*, excepting the small amount involved in carrying it away in nearly radial directions.

The necessity of this may be illustrated by the case of a pair of geared wheels, with badly spaced teeth, acting together—some teeth strike hard power-wasting blows, and others do little or nothing. Abruptly-varying water pressure acts in the same way, but with still greater waste of power, by reason of the fluidity of the impinging masses, which allows them to fly off, whirl around and impede other parts of the current, so that different masses of water collide and waste their power in mutual opposition, instead of acting together against the wheel.

Probably many turbines of this and other kinds lose largely by water running out to waste through the annular clearance spaces between the rims of the wheels and the stationary parts by which the water reaches them. Such leaks may be caused by having the water strike the wheel too hard, *i. e.*, encounter too much resistance at entering, or by improper construction. When these faults are avoided, there appears to be no such loss.

The difficulty of laying out curves which will give any desired distribution of pressures throughout the lengths of the floats is caused by the fact that all the particles of water do not describe identical paths in space. Every particle flowing on the concave wall of the bucket, *i. e.*, of the float, necessarily traces a path in space wholly determined by its velocity outwards, the form of the float and the angular motion of the wheel. But the control of the concave side over the paths of the particles not in contact with it diminishes increasingly as their distances from it increase.

It is not difficult to determine the path which results from the assumpion that all the particles move alike, as is done very plainly and clearly in the "Lowell Hydraulic Experiments." But readers are there cautioned against undue dependence upon this, by the showing that the path so found for the outer part of the wheel differs widely from the well-ascertained facts, and the cause of the discrepancy is explained substantially as above. The approximation is sufficient for the deductions there in question, and the author judiciously abstains from using it in other ways where it would be misleading.

If the mean path is known, the pressure produced upon any part of the float can be ascertained. But the approximate path found as above differs so much from the true one that it is of little value as a basis for estimating and regulating the distribution of pressures on the float; if unintelligently employed, the results would be worse than useless. The desideratum is to ascertain the true mean path, and then work through it.

Boyden studied this matter, and others connected with turbine designing, for several years with first-rate intelligence, immense energy and

large expenditures in practical tests. It appears to me that he brought his theories substantially to perfection, and it is much to be regretted that so little knowledge of his work has been communicated to the public.

I never before heard any intimation that the design for the Appleton turbines, made in 1846, was one of Boyden's masterpieces; on the contrary, this was one of his earliest designs—probably his second one. As to the 88 per cent. of utilization, Mr. Francis states, properly enough, that he was responsible only for the computations; but I am confident that he never intended to cast the slightest suspicion on the accuracy of the data. He was on terms of friendly intimacy with Boyden, and if there had been anything *shaky* about the data, probably he would have known it, and if so, would certainly have called attention to it in a proper way. Further than this, I can testify from much personal knowledge, acquired later, that I never knew a more upright, intelligent and painstaking experimenter than Boyden.

His study of the subject was made largely between 1846 and 1849–50, when the Atlantic turbines were built. The experiments in testing one of these were made in 1851, but the award of the referees, which has been mentioned, was several years later, long after the completion of the principal weir experiments at Lowell in 1852.

Any adequate discussion of this case would be too long for admission here. The referees awarded a lump sum merely, on claims for extra utilization and several other things.

In the Appleton and other early turbines where wooden flumes were used (for economy of first cost), the "spiral approach" was adopted, *i. e.*, the water was introduced into the upper part of the flume or *tub*, on one side only, so that it would gyrate and descend helically, instead of turning directly down at the entrance. This made a cheap and simple form of inlet yet without abrupt turn of the current or great loss in turning. The gyratory motion was expected to aid in directing the water on to the wheel properly, but it seems practically certain that it would sweep across the tops of the guides to a very considerable and prejudicial extent.

Cast-iron *quarter turns* and flumes of the best design, such as were used in the Atlantic turbines, are much better. By a properly graduated diminution of diameter, no eddy is allowed to form in the current passing down around the curves, and all the water comes down to the guides in approximately vertical directions, these guides being high enough to meet the water before it begins to flow out toward the wheel; thus the water passes down between them smoothly, then turns gradually outward and reaches the buckets rightly directed, but with only a minute loss of *vis viva*.* The losses from collisions in entering the buckets can also be made very small.

Assuming a medium fall of, say, 25 feet, and best conditions, the water passes out from the wheel, nearly radially, with a velocity of about 9 feet per second, corresponding to a fall of $1\frac{1}{4}$ feet, or 5 per cent. of the whole fall. But as the outflow is on diverging lines, *i. e.*, with constantly dimin-

* Guides have often been made too low, so that the water flowing outward cuts across their tops, making large waste of power.

ishing velocity, the escaping water parts with some of its *vis viva*, and the portion surrendered is partially utilized in reducing the back pressure on the outlets, leaving perhaps 4 or 4½ per cent. going to loss. If there is a diffuser, about 3 per cent. more of the whole *vis viva* is utilized; and the water passes out with a velocity of less than 3 feet per second, corresponding to a fall of about ⅛ foot, or one-half per cent. of the whole fall, in the case assumed. This indicates that not over 1 per cent. is used up by friction, cross-currents, etc., in the diffuser.

There seems to be no good reason to doubt that all the losses outside of the wheel can be kept within the narrow limits here indicated. The losses in the wheel may easily vary from small to very large percentages, according to the fitness or unfitness of the lines of the buckets. With the best forms, I believe it is practicable to approximate closely, so far as disappearance of *vis viva* is concerned, toward the conditions of flow through good-shaped stationary *chutes* giving currents of like dimensions. The friction on the walls is more injurious in the case of the moving chute; it not only uses up *vis viva*, but uses it in dragging backwards on the wheel. Aside from this, the cases are much alike; improper forms will produce whirls, collisions and waste of power in either. The introduction of the element of motion of the chute, under transfer of *vis viva*, complicates the investigation, but does it make any radical difference between the two cases? A stream of water can be deflected by a stationary obstacle, with inconsiderable loss, aside from surface friction: pressure is produced, but motion not being permitted, the stream retains its *vis viva* and changes its direction. If the solid obstacle is allowed to move, *vis viva* is transferred to it from the stream, and the latter shows it by loss of velocity. Is there any inherent impossibility of carrying on this transfer without loss? Is it anything but a question of knowing how to make the proper co-ordinations of forms and motion?

The frictional resistances to the motion of the running parts, *i. e.*, the wheel and shaft, constitute the only considerable item of difference between the amount of power communicated to the wheel and that yielded by it. Estimating these by weighing the resistance at slow speed, they are found to be very small when the wheels are well supported, as in the case of the Atlantic turbine, where the weight is carried in a well-made suspension box hung in gimbals.

The feeling that 85 or 88 per cent. is the maximum attainable is doubtless a very natural one, but many facts, of more or less weight, in my experience, point to a much higher value—in the vicinity of 95 per cent.—and have led me to a review of the *à priori* reasonings about the matter, in the method and with the results above indicated in a general way.

BY MR. EDWARD ATKINSON, PRESIDENT OF BOSTON MANUFACTURERS' MUTUAL FIRE INSURANCE COMPANY.

You are rash, Mr. President, in calling upon one who is neither engineer nor mathematician to take part in this discussion. My function is to pick your brains—I hope not your pockets—to find out all that you know, to concentrate it, and to endeaver to induce all who intend to construct mills or works which we are to insure to build them in the right way, under the advice of thoroughly competent engineers. We do not attempt to make

working plans ourselves in the insurance company of which I am president; all that we can undertake to do is to give sketches and suggestions by which owners and engineers may be guided.

I have listened with the greatest interest to Mr. Sawyer's paper. One of the mills of his construction was chosen by me as a model to illustrate a recent article in the *Century* magazine upon slow-burning construction. I have taken a few notes from his remarks, and will refer, in a desultory way, to some of the points which he has presented, and I may develop them, perhaps, a little further.

I first take note of his criticism in respect to the use of the English language. There is no word that has been more perverted from its original meaning than the term *manu*-facture: it really means to make something by the hand—in point of fact, the further we get from the hand work the more we apply the term *manu*-facture to the *mechani*-fabric.

There has been a great change in our Southern land from hand work on textile fabrics to the development of the factory. A great population has been added to the consumers of factory-made goods by this change, which accounts for a very considerable part of the extension of the Southern cotton mills. We must not, however, let our imagination run away with us in the matter of factories. The branches of manufacturing which are centred in great buildings where many persons work under one roof, do not yet give occupation to more than 10 per cent. of the working people of this country. The hand and the head must be applied together in by far the greater part of our work, where the work is to be done which cannot be concentrated in a factory.

With respect to the construction of the factory, we have been controlled in this country by the greater abundance of timber and the excessive cost of iron, so that our customary factory varies greatly from that of European countries. The form of our construction has also been to some extent controlled by the original placing of the factories by the site of a water power. But since water power may be said to have passed by as a motive power, except where it has already been developed, having proved to be a bad investment when entered upon for mere purposes of development in almost every case; and since steam power is being substituted for water power, we may choose the place of the factory, therefore we may take the work out of the crowded city or out of the narrow valley, and spread the mills not only over a wider area of country, but over a larger piece of ground in each instance, thus diminishing the number of stories and broadening the mill.

I think a great many water powers may be hereafter developed to be applied to the generation of electric power. In this way a great many gorges may be made use of where there has heretofore been no place to put a mill by a dam site.

The substitution of steam for water power was a subject treated many years ago by good David Whitman, whom some of may have known, and whom many of you have heard—the man who knew more of cotton spinning than any one of his time, and perhaps more than almost any one of the present day. His computation was that one could not afford to go any distance that would cost $3 per ton of stock for transportation to the mill and $3 per ton of goods back to the market, even if the water power

were given him for nothing. And that computation was made when the best work of the engine was three pounds of coal per horse power per hour. We are diminishing the power required in the factory and at the same time diminishing the cost of power: this is in part due to the greater stability which we give to the construction of our factory buildings. It is for that reason as much as for any other, that I have so urgently advised the construction of one-story mills. I think very little attention had been given to the effect of vibration on the wear and tear of machinery until Mr. Woodbury's experiments on friction and vibration in connection with the investigation of lubricants. In a high mill it seems to me that the connection of the posts one with another supported with small pintles is the weakest spot, and most likely to lead to instability in the mill and to utter destruction in case any part of the mill is broken down by fire. I have long thought that a way would be invented by means of which the posts could be brought against each other and bound together vertically, while the floor beams might be laid against the posts, and held up in such a way as to roll off from their bearings in case of a break, just as they are laid to roll out from the side walls, without any strain.

(In connection with this report of my remarks which I have been asked by the President to make, I will present two studies in the substitution of other methods for connecting the posts and floor beams than those in common use, in which the pintle is done away with.)

The danger of laying the top floor so close as to strain the walls by expansion of kiln-dried top floor has often been considered and guarded against. I am somewhat surprised by the statement made by Mr. Sawyer in regard to planks shrinking lengthwise so much as to tip the posts. Such a case has not come under my observation in a way to attract my attention. I have been in consultation with our Mr. Buck for the last month, in devising some method of adjusting posts by other devices in place of the pintles.

Mr. Sawyer has referred to the urgency with which we have pressed the construction of the one-story mill, although he does not name myself or my associates. The first of the large mills constructed in this way was not consistent with the plans that we advised, and it gave the one-story mill something of a black eye. Later many such mills have been built. In one instance, where the machinery is very heavy, the Plymouth Cordage Company, after the fire had destroyed a very substantial four-story mill which was not very old, being one of two of like kind, I suggested to the treasurer to construct a mill one story high, and to operate his machinery with ropes. But I also advised him not to take my advice, rather to get the best advice from the best consulting engineers he could find. He then consulted Mr. Leavitt, and employed Messrs. Lockwood & Green ; the plan was carried out in spite of the warning which I also gave him that the one-story mill would bankrupt the second spinning mill which had not been barned, and would render it necessary for him to take it down and reconstruct it on the one-story principle. The second of the two spinning mills, which was of the ordinary model of solid construction, has been taken down, and the machinery has been placed in an extension of the one-story structure. The reasons which lead to this form of mill-building being adopted affect especially weaving and heavy work

which is subject to great vibration. Where the parties think it more judicious to build higher mills we, on the whole, give the preference to a two-story mill constructed of timber and glass, very heavily framed, as compared to brick and stone, foundations being carried to the lower window-sills.

When buildings are from necessity or choice built higher than two stories, we think four stories the best, with separate fire-proof belt chambers and fire-proof stairways, and with few or no belt-holes in the floors. This is the latest model carried out by the Amoskeag Company, and in some of the later mills in Fall River and in New Bedford.

The English fire-proof mill is a very much more costly structure than ours, and is probably no better, if as good, for the work. The cost of our slow-burning mills is much less than that of the average fire-proof mills abroad. Iron being very treacherous when exposed to heat, the combustion of the contents of the factories will often tear the fire-proof mill to pieces, although it may not be burned.

In England, the spinning of fine yarns has been brought to so close a margin as to control the construction of the mill. The modern spinning mill is 126 feet wide inside, which gives just the clear width required for the mule of 1,200 spindles to be operated by one man and a boy; anything beyond that would not be worked profitably; anything less than that would not occupy a man's full time.

In these mills the walls are very thick and the windows are very wide, about 6 feet of window to 4 feet 4 inches of wall in each bay of 10 feet 4 inches, the lights being carried flush with the ceiling above.

There is yet a great margin for the work of the engineer. There is one problem to which I wish to call your attention. I brought it before the cotton manufacturers many years ago; to wit, the preparation of the air in summer as well as in winter. It is a singular fact that by a process of natural selection—probably without knowledge of the reason why—there are not now many cotton spindles in Manchester, England, where the art was first established. Many of the old mills are dismantled, and nearly all the spinning mills are now along the crest of a ridge about 800 feet above the sea level at the edge of the moors which stretch away to Scotland. At that point the humidity brought in by the Gulf Stream is condensed, and while the rainfall is little more than one-half of that of New England the humidity is constant and very even. It is upon that that the work depends.

Many years since I suggested the preparation of the air, which serves only as an instrument for carrying moisture, prior to its introduction into the slasher of the cotton mill, by passing it over ice so as to cool and dry it, and thus put it into condition to take up a great volume of moisture without being heated above 120 degrees Fahrenheit. If the cotton or woolen fibre is subjected to a heat above 120 degrees Fahrenheit, it is apt to become brittle. I also ventured to suggest taking the air for the spinning rooms from the outer end of the tail-race, especially in the dog-days, so as to bring into the mill the air which had gone down with the cold water, washed and reduced in its humidity to the point of temperature at which it may be found in the wheel-pit. An experiment in this direction is just now being made for the first time within my knowledge. Some-

thing corresponding to this was adopted by our Mr. Wm. B. Whiting many years ago, when he was a manufacturing agent in the mill of which he had charge, with good results. But we are very near the point where we can make the cotton mill *a sanitarium!* The ammonia method of reducing the temperature of the summer air below the freezing point is now in common practice in breweries, cold-storage houses, and meat-packing establishments. I am investigating this subject, and have lately put a plain question to one of the large machine shops in the West where they make the ammonia cooling engines. I put the question in this way:

"At what price will you lay down a plant for furnishing a cotton factory 300 feet long, 100 feet wide, four stories high, 12-foot post, with a constant volume of air at a uniform temperature of 70 degrees throughout the summer months, such air to carry the amount of moisture short of saturation which air at that temperature is capable of holding in suspension."

The proposition was received as if it were entirely commonplace, and they stated that the plant could be put down with all the fittings for $15,000. I am now following it up to see what it would cost to operate the machinery. I think there is a great field here, not only in the preparation of air and cooling it in the cotton mill, but in all sorts of works, in offices and in dwelling houses, etc., etc.

I will also venture to suggest another line of investigation to which I have already referred incidentally, to wit: the vibration either of the mill or of the machine as a cause of friction, and therefore of wear upon all parts of the machinery.

Among my reminiscences is that of a woolen mill built on fire-proof principles, in the State of New York, and therefore not requiring the services of the underwriter in the opinion of the owners. I was assured that the machinery came into such direct contact with the iron members of the frame of the building that no one could run it, and no one seemed to know what was the matter until a Yankee superintendent was engaged. He put in heavy timbers and freed the machinery from contact with metal, and afterward there was no difficulty in operating it.

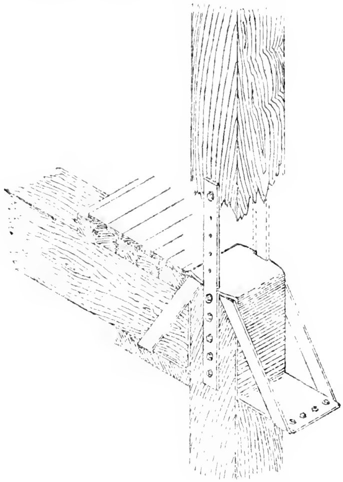
This example and my observation of Mr. Woodbury's experiments in lubrication gave me the idea of incorporating hard wood blocks in the frame of a high-speed machine, so as to cut off the contact of metals at certain points. This is pure theory, but it would be easy to test it. For instance, the spindles in a modern spinning frame run 8,000 and even 10,000 turns a minute; the vibration of the spindle rail is very perceptible to the touch. If that rail rested on hard wood blocks, I venture to *guess* there would be less vibration, less friction and less noise. I will record my claim to this as a new and useful invention, and see if I cannot get some one to put it in practice at once. Since the meeting a trial has been entered upon on which I may claim a patent.

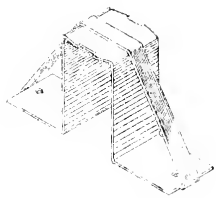
While revising my remarks given at the meeting for publication, I may venture to treat a little more fully one very important subject to which reference was made, to wit: the weakness of the common arrangement of caps, pintles and base plates in the arrangement of the columns of a mill.

We observe to our cost that nearly all existing arrangements for the adjustment of posts one above another are faulty, for the reason that if a single column is broken, as iron columns are apt to break under fire and water.

or if a wooden column is burned, or if a part of the floor falls, the key to the whole structure appears to be destroyed or endangered. The strain upon other columns by the removal of a part of the beams, leaving the slender pintles unsupported at the side, weakens the whole structure and is very apt to be the cause of great damage to or of complete destruction of the mill building.

I now venture to submit a crude study of the adjustment of posts each to the other in two different ways. In this adjustment I have tried to keep all the contingencies in mind.





This is a mere suggestion. It is held by some mill constructors that the present base, cap and pintle constitute a better mode of construction than any saddle that can be made, and that no change in modern practice is called for.

It is also held by others that when floors or beams are so injured by fire as to endanger the posts, it would be better that all should fall together.

The head of the lower post is carried above the level of the floor, so as to lift the base of the next post free of the wash water. The floor beams rest in an iron saddle, which, in one diagram, is braced at the sides: in the other, probably the better method, it is braced by an iron bar carried over the top of the saddle between the ends of the posts, and cut into the end of each floor timber, if single timbers are used, or between the two pieces, if the beams are in two parts. This saddle, being made a half inch wider than either post, will have a slot cut at each side, through which slot a vertical strap of iron is to be carried, which is to be bolted to the two posts.

A dog may be introduced in the saddle by turning up a part of the end, or in any other way, so as to catch on the under side of the timber where it rests upon the saddle. Underneath the stirrup, which is exposed upon the under side of the floor beam which rests therein, a two-inch plank may be fastened to protect the iron from the heat of a fire, or additional strength may be given by placing a hackmatack knee under the stirrup, so as to strengthen as well as to protect it from heat.

The end of the floor timber cannot well be rounded, as it may be where the end of the timber enters a brick wall; yet I think this construction,

braced as it would be in every way, would stand, even if the floor on either side of it were burned away, or if the next post was destroyed.

I submit these diagrams merely as studies, subject to criticism and suggestion, and shall presently have all the stresses computed.

I think a good deal of work has yet to be done in the application of hackmatack knees to the support of floors. They have several times been introduced into high and narrow mills at our suggestion, in order to stiffen them, but have not yet been used to any great extent in original construction, except in one-story factories.

BY MR. C. J. H. WOODBURY, SECOND VICE-PRESIDENT BOSTON MANUFACTURERS' MUTUAL FIRE INS. CO.

The New England mill is one of the most complete works of engineering, as far as the fitness of means to ends with an economy of material is concerned, and its radical difference from all other buildings is that of the floor, constructed by laying thick plank upon heavy timber beams. This floor conforms to conditions of stability, facility for placing machinery and shafting as may be desired, diminution of vibration, and great resistance to fire. I have never known a mill plank floor, if without openings for belts or stairways, to be burned through by a fire in the contents of the room below.

In contrast with this, the present type of English fire-proof mill, so-called, cost very nearly twice as much per square foot of floor as the American mill, and this floor, constructed of iron and concrete, weighs over one hundred pounds to the square foot, or four times as much as that of the corresponding American mill.

The present use of iron columns, in English mills, rendered necessary perhaps by the great weight of the structure, is in no wise different from what has already yielded in many fires of the contents of a room in American buildings.

In connection with the use of timber, it is necessary to take great precaution in avoiding dry rot by providing means for the circulation of air around the timber. Wherever it is necessary to place floors a short distance above the earth means should be adopted for ventilation by placing apertures through the foundation of the mill, and also connecting such spaces to the picker room or some place requiring a current of air in order to force a circulation underneath the building.

In the construction of columns it is desirable that the base of the column should be above the floor, and instead of the usual manner of placing it in a cup, to place it upon a flat pedestal, holding it in its position by means of a projection which fits in a hole bored along the axis of the column, and in this manner preventing an accumulation of dampness which is inevitable in many cases where the column rests in a cup.

Another defect of construction, occurring in storehouses more frequently than in mills, is placing wooden bolsters over the columns, instead of iron caps and pintles. The transverse contraction of these large beams in the process of seasoning varies from three-eighths of an inch to double that amount, and therefore throws the floors of the building out of level to that measure, and the error is a cumulative one from story to story. There is also a liability of compression of the beams when sup-

ported directly on columns, as the experiments for the Factory Mutual Insurance companies on the testing machine in the United States Arsenal, at Watertown, showed that the resistance of timber to transverse compression was about one-third of its resistance to longitudinal compression, and therefore the cap on the top of a wooden column should spread out to sustain an area of timber three times that of the end of the column.

The improvements in mill construction nearly all originate among the cotton mills, owing to the close competition and the fact that cotton manufacture is largely mechanical, a larger proportion of the cost of the finished product being labor than is the case in either woolen or paper mills. In the latter a large proportion of the success of the manufacture depends upon the degree to which the designs please the public fancy, and also the amount of blending in the selection of the stock so that it gives the best appearance possible for the cost of material.

It is especially true of paper mills that comparatively little attention is given to the separation of the various operations of the establishment devoted to different processes, so that at times the whole establishment is subjected to the hazard of the more dangerous processes. Furthermore, in such instances the storage of raw material and finished product is not well separated from the hazard of the manufacturing portion of the establishment.

There have been great improvements in the last few years on matters connected with the distribution of the main power in mills, and for these improvements Americans are largely indebted to English practice. Instead of the belt porch, which is more or less open in free communication to the mill, an inside tower contains the pulleys and belts, the power being communicated to the various stories of the mill by shafting which extends through the walls. In this manner the power is distributed without being accompanied by forced currents of air through large openings.

In English practice, ropes are largely used for main transmission, but there are wide differences in respect to the methods of their use. The angle of the grooves should be that whose tangent is the coefficient of friction of the ropes to transverse sliding on cast iron, and yet I have noticed that the difference in practice on the straight grooves varies from thirty-five to seventy-five degrees, and in other instances elliptical grooves are used, of which the angle of contact cannot be readily determined by observation. It appears to me that rope transmission is more generally used in the West than in New England. There are several modifications of English methods, notably that known as the Dodge system of arranging the ropes, and also the Walker system, in which the grooves are placed in rings on the pulleys in such a way as to adjust themselves to the strains in order to render the pull on each of the ropes uniform. The opinion in England is not unanimously in favor of rope driving. A part of the adherence to the old method of driving with an upright shaft, distributing on each floor with bevel gears, may be due to the fact that the belting in England did not appear to me to be so uniform and well stretched as the belting used in America.

While at Geneva I saw a watch factory under construction which was being built of iron and concrete, the motive being similar to that of the

design of the iron mill exhibited to you this evening by Mr. Grinnell, although the method of carrying out the design was far different. The ends of the mill were of stone, and the walls of upright I-beams extending between the windows, and of concrete from the windows to the floor. The floors were made of joists placed between the I-beams and the boards covered over with cement. The iron window sashes were fixed, but a small portion of the upper sash would swing for purposes of ventilation. The roof of this mill was a square roof consisting of tiles resting upon a joisted frame and inclosing a hollow, unused attic. The partitions through the mill were made of tiles set on edges and joined together with plaster of Paris.

There did not appear to be any controlling system of mill design in proportioning and arranging a building for the specific use of manufacturing in the manner customary in America.

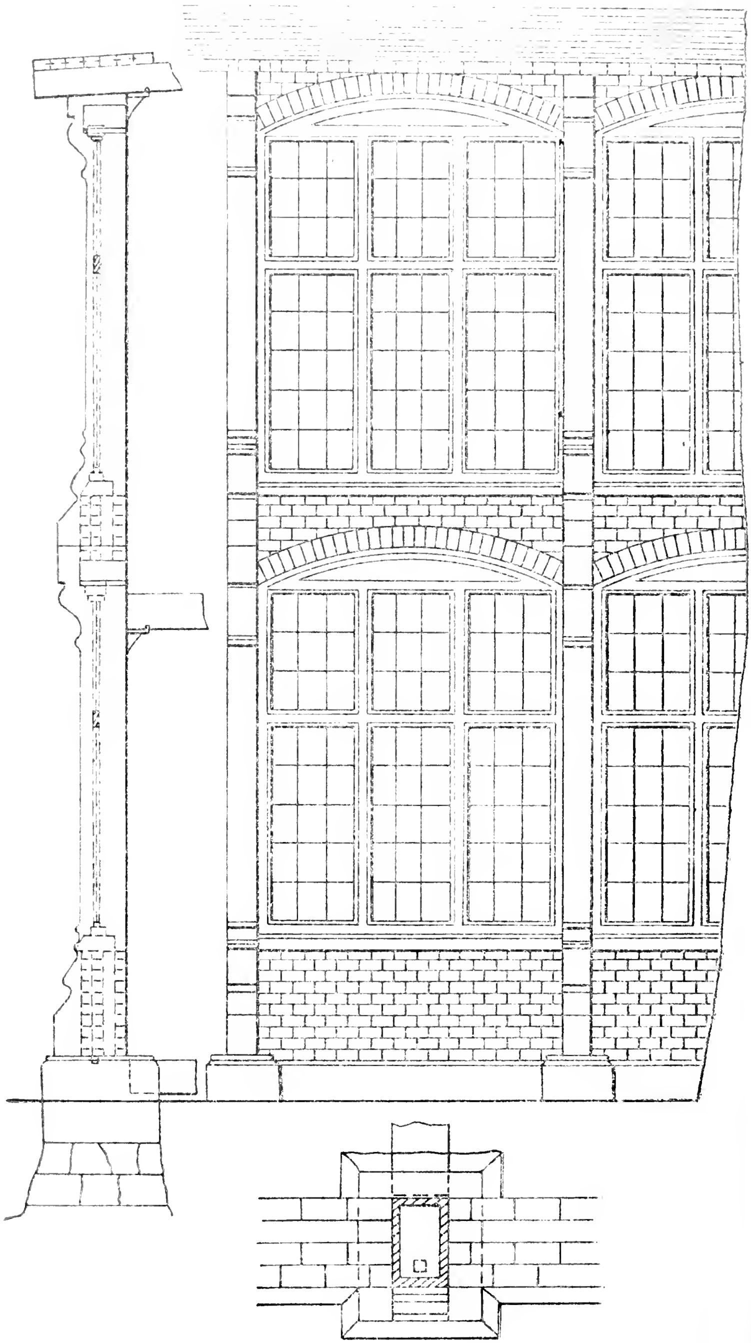
BY MR. EDMUND GRINNELL, PROPRIETOR OF NEW BEDFORD IRON FOUNDRY.

Among the many changes in mill construction during the last 30 or 40 years, made necessary by the use of improved and more economical machinery, few are more noticed by the general public than the great contrast between the high and narrow mill built in the fifties and those later productions of the engineer's skill as shown in the mills completed in the last year in Fall River, Lawrence, New Bedford and elsewhere. From a structure of six or seven stories, and only, perhaps, 60 feet in width, with high pitched roof, has evolved the modern mill, of not exceeding four stories, with flat roof, and its magnificent proportions of 350 and over by 128 feet.

While going over one of these, complete and perfect in almost every respect, the writer was struck by the difficulty, in so wide a mill, even with its comparatively large windows and high studded walls, of obtaining a sufficiency of light, in quite a large area in the centre of the mill. The idea at once suggested itself of the adaptation and modification of a method of construction long used in commercial buildings with perfectly satisfactory results. The use of iron columns in one or two stories on the outside of a building, carrying the walls above, is common the world over, and results in as near as possible an unobstructed ingress of light.

The modern mill of four stories has generally, on ten-foot bays, a brick or stone pier of four feet between each pair of windows, leaving not over six feet for the window and frame, or a loss of 40 per cent. in the light. Substitute for the walls of brick and stone an iron column, cast in four sections, to each bay, bolted to an iron plate, this in its turn bolted to the foundation, and each section of the column bolted at top and bottom through flanges to the section above and below it, with brick arches of three courses of brick above and below the windows, sprung from skewbacks on the columns.

The first-story column would be 12 inches by 20 inches, with base projecting on the face 10 inches, giving a 30-inch bearing and a cap projecting 8 inches from the face for a bearing for the column above. The second-story column would be 12 inches by 18, with base projecting 10



inches and cap 8 inches. The third-story column would be 12 inches by 16 inches, with cap and base projection the same. The fourth-story column would be 12 inches by 14 inches, 10 inch projection at the base, and with brackets or recesses at the top to secure the rafters to. This would give an opening for window and frame of 9 feet, a loss of only 10 per cent., and a gain of 50 per cent. over the brick or stone pier. The inside construction would be the same as in the ordinary mill, the beam resting on an iron bracket cast on the back of each column and fastened to it by bolts or lag screws, as a fixed or hinged joint was thought best. The ends of the mill would be built in the same way, headers being run from the next beam to the brackets on the column, and a diagonal header to each corner column. This corner column, although actually carrying less weight than the others, for the sake of symmetry and good proportion could be made 20 inches by 20 inches, and to secure it and hold the thrust of the adjacent arches, should have a wrought-iron tie-rod, say 1¼ inches in diameter, run from it through the brick arch to the next two columns on each side. The natural stiffness of cast iron, combined with the deep bearings of the columns tied to each other, and the whole by the beams, four inch planking, floor-boards and roof, would give a structure absolutely rigid, and capable of withstanding the oscillation of the heaviest and highest speed machinery.

In addition to the gain in light a very important gain could be made in the time required for building an iron mill, it being easily possible, so far as the erection of the iron work is concerned, to have a four-story building ready for the roof within four weeks from the time the foundation is ready to receive the columns.

As regards the cost of a mill built as above, a liberal estimate compared with the actual cost of a mill which went into operation during the early spring, with the foundation, chimney and interior construction the same, shows that the iron and glass mill could be built at a reduction of about four per cent.

Any objection to the use of cast iron on account of its liability to failure when exposed to fire, could be overcome by the use of a proper thickness of metal or the filling of the inside of the column with concrete. The advantages of this construction are :

First—A gain of fifty per cent. additional light, which in the manufacture of the fine goods now demanded by the market is all important.

Second—Less time consumed in the putting up of the building, and from the greatly reduced amount of masonry a comparative immunity from the vexatious delays consequent on laying brick and stone. And these advantages are obtained at a slight decrease in cost.

BY MR. CHARLES T. MAIN, SUPT. OF LOWER PACIFIC MILLS, LAWRENCE.

Mr. President : As long as the discussion has taken such a wide scope, I should like to describe in a few words the type of engine which is now coming into use for manufacturing purposes.

It is the compound engine, but so arranged that such low-pressure steam as may be used for various heating purposes can be taken from the

receiver between the high and low pressure cylinders after it has passed through the high-pressure cylinder and there doing work.

The size of the low-pressure cylinder, as compared with the high-pressure will depend, other things being equal, upon the average portion of the steam exhausted from the high-pressure cylinder which is to go into the low-pressure cylinder. Thus, when no steam is taken from the receiver, the proper ratio of areas of cylinders for 125 pounds boiler pressure is about 1 to 4.

In a plain cotton mill an average of about 25 per cent. of the steam exhausted from the high-pressure cylinder can be used for heating and slashing, thus leaving 75 per cent. to go into the low-pressure cylinder. The area of that cylinder, then, as compared with the high-pressure, would be three to one.

As the amount of colored work increases, the amount of low-pressure steam which can be used increases and the ratio of areas of cylinders decreases. This type of engine can be used to advantage when as high as 75 per cent. of the steam exhausted from the high-pressure cylinder can be used for various heating purposes. At this point the high and low pressure cylinders would be equal in area. Beyond this point the high-pressure non-condensing engine is the proper one to use.

As the amount of exhaust steam taken from the receiver is variable, the pressure in the receiver would be variable with a constant cut-off in the low-pressure cylinder. But in order to keep the pressure in the receiver constant the cut-off on the low-pressure cylinder is arranged so that it can be changed to admit the amount of steam which is not needed for other purposes.

The first arrangements provided for changing the cut-off by hand. The engineer had to watch the gauge showing the pressure in receiver, and increase the cut-off when the pressure increased, and decrease the cut-off when the pressure diminished, the high-pressure cylinder taking care of the work.

There are now two attachments which can be applied to the engine which will change the cut-off in low-pressure cylinder automatically by the pressure in the receiver.

With such an engine as described a variable amount of exhaust steam can be used, and there is no need of admitting any live steam into the low-pressure system of piping until the cut-off on low-pressure cylinder has reached its minimum allowable, and there is no need of blowing off exhaust steam until the low-pressure cylinder has taken steam full stroke.

At the present time there are seven textile manufacturing concerns which I know of which have engines arranged for using steam from the receiver for various heating purposes, and the first engine of this sort which I know of for use in a paper mill is now being erected.

BY MR. STEPHEN GREENE, OF NEWBURYPORT, MASS.

The best modern practice in mill engineering follows the true method, namely: That of considering, first and chiefly, the necessary machinery for producing a given product of a desired quality and arranging this in proper order. All questions of construction of buildings must be subserv-

ient to this idea and must conform to it. Great difficulty is experienced in endeavoring to adhere to any set plan or arrangement, as the frequent improvements in machinery require constant modification.

In the few moments I may take I may simply touch briefly upon one or two problems in mill engineering. One of the somewhat difficult problems we meet in mill construction is to secure a satisfactory floor, where no space can be allowed beneath. Our experience has taught us that the most satisfactory results can be obtained in such cases by first laying a concrete composed of gravel and coal tar materials, and upon this completed surface lay plank either of hard pine or hemlock simply fitted together. Upon these plank, which should be no less than three inches in thickness, the top flooring may be laid and should be laid across the plank. The cases are very numerous where floors have been laid upon concrete and have completely failed. The cause in nearly every instance has been due doubtless to the inserting of timbers in the concrete, to which the planking has been nailed. This method is to be condemned, as it allows dampness to enter, which insures a speedy destruction of the floor.

One of the interesting problems now before engineers and manufacturers is the means of transmission of power. Within the last four or five years we have adopted in quite a number of cases ropes instead of belting for transmission. Our position at present is simply this: We do not say that in all cases and under all circumstances ropes are preferable to belting, but we believe that in very many difficult problems of transmission, especially where large amounts of power are to be used, the problem is more easily and more satisfactorily solved by the use of rope than could possibly be done with belting.

The requisites for a successful running of the ropes we consider to be :

First—Having a proper diameter of pulleys, which should not in any case be less than thirty times the diameter of the ropes.

Second—Having a proper form of the groove.

Third—Great care must be taken to have the grooves properly smoothed after being turned.

Fourth—Allowing the rope to have a reasonable amount of sag.

We are very much interested in the matter of rope driving, and I have to say that we have not yet learned of a case of failure in rope driving where the ropes have been properly arranged and have had a fair chance. There may be such failures, and I should be very glad to be informed of the fact if any exists.

BY DESMOND FITZGERALD.

There has been a fire recently in the building No. 17 Kingston street which, it seems to me, is exceedingly instructive. This building was erected by Robert K. Snow, of Chelsea, just after the great fire. I asked Mr. Snow to accompany me on an inspection that I made of the building within a few days, and before the débris of the fire was removed. The floors are solidly built of planks and boards, and were so little injured as to cause me some surprise. I took some notes of the construction, and intended to give the Society an account of the details, but I have heard that Mr. Rice was employed in a professional capacity to re-

construct those portions of the building which were damaged, and as he has undoubtedly the correct data, I will call upon him for a full description.

BY L. FREDERICK RICE.

The *floors* are supported upon girders, which rest on cast-iron plates 2 inches thick, bedded in the brick party-walls and projecting therefrom 4 or 5 inches.

The girders enter the walls 4 inches. They are built up of spruce planks, spiked together; four 3-inch × 12-inch planks being on edge, side by side, and one 2-inch × 12-inch plank being spiked to the bottom, thus forming a beam 14 inches deep by 12 inches wide. The sides and bottom of each girder are cased with $\frac{7}{8}$ inch sheathing. The girders are spaced 7 feet $2\frac{1}{2}$ inches apart, on centres. Between the ends of the girders and close against the walls are set pieces of spruce plank 4 inches thick, resting upon the iron plates and spiked to the girders. These are also faced with $\frac{7}{8}$-inch sheathing.

The floors are formed of 2-inch spruce plank, square edged, without tongues or splines, laid diagonally upon the girders, the ends being supported by the wall pieces last mentioned.

On this is laid a second flooring of $\frac{7}{8}$-inch spruce, diagonally and at right angles to the 2-inch planks, and above this a top floor of $\frac{7}{8}$-inch hard pine, laid at right angles to the girders, or parallel to the party-walls. On the under side of the 2-inch planks, between the girders, is a ceiling of $\frac{7}{8}$-inch matched and beaded spruce. The angles between girders and ceiling are filled with a small spruce molding. The girders and ceiling are painted.

The elevator, which is in the northerly corner of the Kingston street front of the building, is inclosed by a stud partition, covered with $\frac{7}{8}$-inch spruce sheathing, protected on the *elevator* side by a facing of tin. Double doors give access from the elevator to each story, and it is lighted by a window in each story. Over the shaft is a 3-foot × 3-foot skylight and ventilator.

The doors are of the ordinary paneled construction, faced with tin on the *elevator side only*. The elevator is used in common by the occupants of both this and the adjacent building, the doors of access to both being upon the same level, but on opposite sides of the shaft.

The stair from the fourth to the fifth stories has a stud partition at each end of the well, projecting 6 or 7 feet from the wall, but is *open toward the lofts*. In the third story the stair well is entirely inclosed and has a door at the foot of the stair leading upward. The stair-well opening in the fifth floor is about 6 feet × 14 feet.

The partitions inclosing the stair well, and the wall at the back, are sheathed with $\frac{7}{8}$-inch spruce, the latter being nailed upon horizontal furrings $\frac{7}{8}$ inches thick. The stair is against the northerly wall, and about midway between front and rear of the building.

The walls of the fourth and fifth stories, except in the stair well, are not covered—the bricks are bare.

The *roof* was carried upon girders, resting upon iron plates and built into walls, in the manner before described, but spaced about 4 feet 9 inches on centres. The roof girders were each built up of three 3-inch × 12-inch spruce plank, laid on edge, side by side, and spiked together.

On these was laid a roof of 2-inch spruce plank, not matched or splined, of rafted lumber, with pin holes not plugged. These plank were laid diagonally, the ends being supported by short pieces cut in between the girders and against the walls, as before described for the floors.

Upon the 2-inch plank was laid $\frac{7}{8}$-inch spruce, parallel to the party-walls, and this covered with a tar and gravel roof. The roof sloped toward both front and rear walls, with an inclination of about one-half inch per foot. The under side of the roof planks, and the surface of the girders were not sheathed.

At some time the floors of this building have been loaded to such an extent as to cause a permanent deflection of the girders—in some cases as much as $2\frac{1}{2}$ inches—in consequence of which the Building Inspectors' Department of the city notified the owners that the floors must be strengthened.

The writer was consulted by the owners as to the best method of strengthening, and visited and inspected the building on August 29.

In the fourth and fifth stories, which were used for storage only, goods were piled against the walls to the height of 6 feet to 8 feet, mostly in packing cases, but some woolen underclothing and goods tightly baled had no cases or were open. Both floors were closely piled with goods, with only narrow passages between. The door at the foot of the stair from third to fourth stories was habitually kept locked, access to the fourth and fifth stories being had by means of the elevator.

On Saturday, August 31, between 4 and 5 o'clock P.M., when most of the occupants had left the building, an employé had occasion to go from the basement to the fourth story, using the elevator. Upon opening the doors, he (as reported) saw before him a mass of flame, and startled by the sight, reversed the elevator, and proceeded to the lower stories to give the alarm, *leaving the doors open.* It is further stated that the alarm was given by this man almost simultaneously with that of the automatic fire indicators, with which the ceiling of each story was equipped.

By the fire, which started in the front end of the fourth story, just back of the elevator, the elevator doors of that story, left open by the man who discovered the fire, were burned and destroyed. The light wooden gate, by which the door on the opposite side of the shaft was protected, was burned, but the doors on that side were closed, and no fire entered the other building, nor were the doors in any way injured.

The flames through this open doorway, *burned* the *upper* sash of the adjacent window in the shaft, but only *scorched* the *lower* sash. No flame passed up the elevator shaft. The sash of the window of the shaft in the fifth story is not scorched and the doors of that story, which remained closed, are uninjured *upon the elevator side.* The fire, from the point of beginning, spread along the surface of the sheathing of the elevator shaft and ceiling to the front windows, destroying them, and through them the sandstone facing of the building from thence to the cornice.

It also ran back to the stairway and continued along the ceiling until reaching the rear wall.

It passed up the open stairway upon the partition and wall sheathing, but *without burning the stairs or hand rails seriously*, and continued until reaching the roof, along which it spread to front and rear. The fire *did not break through either roof or floors*, but burned the roof and its girders so much upon the under side (unsheathed, as before stated), as to make a new roof necessary.

No *floor timber* was injured by fire, and not more than half a dozen are even scorched. The *planks* of the fifth floor are untouched by fire, except for about 15 feet back from the front wall, and none are so injured as to require removal. Neither of the *top floors* of hard pine was burned at all, nor did any fire pass below the fourth story of the building.

The fire may be said to have been confined to the sheathing of the ceiling and partitions, the under surface of the roof and the packing cases.

The elevator doors in fifth story are only charred on their unprotected side. Even in the stairway the sheathing was not burned through. The furring is as bright as when first put in, and new sheathing has been laid upon it. The entire exposed surface of the woodwork of both stories was doubtless a sheet of flame, and was left a sheet of charcoal from one-fourth inch to one-half inch thick. Most of the packing cases were so little damaged that they were used to remove the damaged goods in.

The fire was doubtless rapid in its progress and intense in its heat, and the firemen deserve credit for stopping it where they did. Mention has been made of the fact that, "being apprehensive that the floors would be overloaded by the many tons of water thrown into the fifth story," the firemen cut holes through with their axes, to let the water off.

The holes thus cut were three in number, all of them in the fifth floor, and each being of about six or eight square inches in area. Two or three others were begun, but the plank were not penetrated.

One of the holes was about 5 *feet* from the *elevator*. The second was about 5 *feet* forward, and the third about 12 *feet* in rear of the *open stair well*, of 6 feet × 14 feet area. After considering the size and location of these holes, their efficacy in relieving the floor from the dangerous accumulation of water may be questioned. The 2 or 3 inches sag in the floor girders would account for the accumulation of water to that depth, and this may have been slightly increased by loose garments falling upon the floor in the narrow passages, and damming the water back from the stairway; but the limited area of these passages makes it improbable that there was any *dangerous* accumulation of water.

The case, as above described, stands as a monument to the efficiency of this method of construction in reducing the loss by fire, and the indorsement is strengthened by the probability—almost certainty—that if the system had not been departed from by omiting to inclose the stairway in the fourth story, the fire would have been confined to that story, where it originated, and the damage to the building and to the goods stored in the fourth and fifth stories reduced by more than one-half.

The cost of repairing the damage to the building, caused by this fire, was about $5,000.

BY JOHN R. FREEMAN.

Prudence in Pillar Design.

Among the interesting points brought out by Mr. Sawyer's paper on mill engineering is one which may well serve as a text for more extended comment, and to which the attention of some engineers and architects should be forcibly directed.

I refer now to his illustrations of the fact that by the seasoning of timber in an extended floor a distortion is liable to occur, and often does occur, which may draw certain of the pillars out of the perpendicular slightly, but yet enough to materially change the condition of the application of the load, and to force the bearings at the ends of pillar out of the condition of evenly distributed contact into the condition of contact all near one side.

I have myself seen numerous instances where this has actually happened, and where unquestionably the load was all applied to one side of the centre. Not only have I seen this uneven bearing caused by the endwise shrinkage of long stretches of plank flooring in factories, but also in a few instances by the twisting of heavy cross-grained timbers to which the pillar cap was bolted, and also by unequal settlement of the opposite side walls of a mill.

This very week I saw such a case of settlement at a factory in New York State, where almost every one of the cast-iron pillars had been put into the condition shown in Fig. 1.

There is a popular misapprehension even among designers and engineers as to just what the condition known as "square ends" means in pillar design.

Many of the convenient and excellent pocket memorandum books for builders published by rolling mills, etc., have overlooked or disregarded the prudent suggestions published 25 years ago by that eminently practical engineer, James B. Francis, in his valuable treatise on "The Strength of Cast-Iron Pillars," that "*When the designer has no control over the execution of the work or guaranty that his directions will be minutely followed,*" *or however well the ends may be finished, providing the weight is very unequally distributed over their surfaces, or if unequal settlements may be apprehended, then the only safe course will be to consider the pillars as with rounded ends,* and in the practical tables presented by Mr. Francis the computations were all made on this hypothesis of rounded ends.

On the contrary, some of these handy rolling mill tables of strength of pillars imply that if only the ends be accurately finished in a lathe, then we may take the strength to be as for the theoretically "fixed end," or *three times as great* as per the more prudent tables of Mr. Francis.

Hodgkinson's experiments indicated that the uneven distribution of the load on a square ended pillar might make a pillar *even much weaker than if it had rounded ends.* Thus in a pillar which had load applied at a point on the end of the pillar halfway between the centre and the side (somewhat like *C*, Fig. 2), the strength was but about half as great as for the same size of pillar with rounded ends.

The general result of the swaying of a pillar from the perpendicular by shrinkage, or by unequal settlement, is to put the pillar in the condition shown in Fig. 1. And for this the strength indicated by Hodgkinson's results was the same as for a pillar with rounded ends.

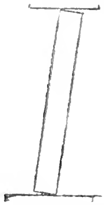


Fig. 1.

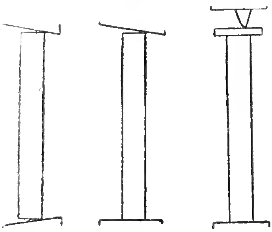
A point which ought to be emphasized in the text books and in the handy pocket reference books is that, no matter how nicely its ends be finished, *a square-end pillar is weaker than a round-end pillar whenever the application of the load becomes unsymmetrical.*

Even the valuable tests of full size cast-iron pillars made recently at the Watertown Arsenal are liable to be misinterpreted by a person not trained to see this whole subject clearly.

The marvelously rigid and parallel platforms of this magnificent machine fulfill very well the theoretical conditions of "fixed ends," or "square ends." and thus develop a maximum of strength in the pillar tested.

It is a matter of regret that we have as yet no tests on full size cast-iron mill pillars made under the conditions similar to those into which pillars are liable to be thrown by shrinkages, unequal settlements or unsymmetrical loads, and that the tests on Hodgkinson's small models should have had to serve for fifty years as almost the sole accessible data.

These conditions could be readily reproduced as roughly illustrated at *A*, *B* and *C*, Fig. 2. For *A* the test should be made not only with angle of inclination so great that rupture would occur prior to the full seating of end due to the gradual bending of pillar, but also with inclination of, say, $\frac{1}{16}$ inch per foot, also, $\frac{1}{8}$ and $\frac{1}{4}$ inch per foot, and for *C* the point of application should be varied to several positions intermediate between centre and side.



A. B. C.

Fig. 2.

Until these much needed tests are made let us urge that the prudent tables of Mr. Francis be followed, rather than the less complete tables referred to above, which imply the imposition of *three times as great a load* upon a pillar of the same size.

A word of caution may also here be added against the custom of casting the cap or bearing for the floor beams in one piece with the pillar. These brackets extending out for a foot each side from over the outside of pillar give just so much more hold for an unsymmetrical load to get in its work of producing an injurious bending moment in the pillar, and thus tend to greatly weaken it under certain conditions, which are not at all unlikely to occur.

The designers of such pillars probably consider that this greater breadth of bearing gives increased fixedness to the end, and thus greater strength.

Tested with fair bearings on the Watertown machine, such pillars would show up admirably, but tried in practice by an unsymmetrical load, the effect might be fatally different.

While we are on this subject of strength of pillars, it appears worth while to present the following experiments on wooden pillars, as they have

considerable value as data, and to some extent serve to supplement the extended series of tests on full size oak and pine pillars made by Professor Lanza, but with the understanding that they bear only somewhat remotely upon the matter I have just been urging.

Some Tests of Full Size Wood Pillars.

I had, a year ago, an opportunity of testing some cylindrical wooden pillars which had all the time, for about 50 or 60 years, been heavily loaded by the floors of a cotton mill, the old Indian Head mill of the Jackson Company, at Nashua, N. H. (A careful estimate showed load on each of these pillars to be 36,000 pounds, or between one-fourth and one-fifth of the crushing strength subsequently shown by the tests.)

Called upon to examine and report as to the strength of this building, I found certain pillars quite heavily loaded. The manager of the mills, Mr. Cadwell, removed these pillars and replaced them by stronger ones, and offered me the old ones for test, and through the kindness of Mr. Frederic Amory, treasurer of the Jackson Company, at whose expense the tests were made, the results in the following table are presented.

The pillars were of an excellent quality of fine-grained spruce. It is probable, from their appearance, that they were turned down from logs not very much larger than the pillars, and the centre of the tree came pretty near to centre of the pillar, and, as may be inferred from the years they had stood in the mill, they were thoroughly seasoned.

By weighing several of the pillars, their average weight per cubic foot was found to be 29½ pounds. The proportion of knots and the size of the knots were not materially different from the ordinary run of good spruce logs of 10 or 12 inches diameter.

The tests were made on the Government testing machine at the Watertown Arsenal. I was present during all of the tests. The top ends of pillars during the test rested on the same cast-iron caps which had held the pillars when in use; the ring, which thus inclosed about ½ inch in depth of the pillar in the almost universal manner of practical use, was found to aid materially in preventing splitting of pillar at the very top when under load.

The tests with inclined bearings were made by taking one of these same cast-iron caps and also a base plate, and planing the back off on a slope of ½ inch to the foot, or 1 in 24.

The annexed table gives the principal results of the test:

1. It will be noted that the first three pillars, Nos. 16, 9 and 3, were tested with load uniformly distributed over both ends in the ordinary manner of tests. In other words, ends were square and bearings were rigidly kept perpendicular to axis of pillar.

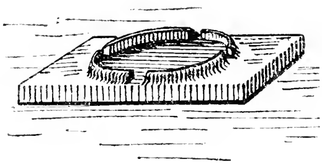
Average crushing strength per square inch, 5,071 pounds.

(This, be it remembered, was for well-seasoned spruce of excellent quality.)

2. For pillars 2 B and 11 B the bottom end had a full bearing rigidly held perpendicular to axis of pillar, but the cap on top of pillar was inclined at an angle greater than is likely to occur in practice. The cup in this cap acted so effectually to bind the end of pillar and prevent its splitting or splintering by reason of the uneven bearing, that the pillar suffered no impairment of strength.

Of course, had there been no such binding of top, the top end of pillar would have splintered, the same as the bottom did in the last three experiments. And thus these experiments *illustrate the great value of confining ends of wooden pillars by hoops or cups for all situations where bearing of load is liable to be oblique.* The experiments illustrate that a cup or ring is much better than a central horn or lug for holding the base of a pillar, and that the base as well as the top should be so confined. To prevent collection of moisture, the cup in base plate can readily be drained. Indeed, the ring need not be continuous, but may have half a dozen gaps in its circumference, each half an inch wide, as illustrated in the following sketch. These gaps also serve a most useful purpose in permitting an inspection of the accuracy with which the fitting at time of erection is accomplished.

Even though shrinkage of wood makes the ring hug loosely, yet it would serve satisfactorily to check the splitting or "brooming up" of end in its incipiency, and, as I now recall it, did so serve in one of the experiments. The sketch illustrates a base plate, but the same notched ring can of course be applied to the top of a pintle.



3. By the last three experiments in the table it is seen that the excessively inclined bearing at bottom of pillar caused the wood to splinter in taking a fuller bearing, so as to induce cracks, which prevented the pillar from sustaining much more than half as much as for a full square bearing. A less oblique angle would of course have shown a greater strength.

4. In experiments on pillars No. 7 and No. 1, it is seen that, as the pillar bent transversely, this tended to give it a full bearing and thus did not induce the degree of splintering noted in the last three experiments. It is seen that this bending moment, produced by the inclination of bearings to an extent greater than is liable to occur with anything but extreme rarity in practice, weakens the pillar about 30 per cent.

5. It is to be kept in mind that the injurious effect of inclined bearings upon pillars of cast iron would be much more severe than for wooden pillars, since the wood, being softer, may yield considerably, and thus tend to give a fairer bearing.

To test the effect of inclined bearings was not the main object of this particular set of experiments; but it was thought worth while to try a few such experiments in connection with the others, as the means were at hand.

TESTS AT U. S. ARSENAL, WATERTOWN, MASS., MARCH 26-28, 1888, OF SPRUCE PILLARS FROM JACKSON CO.'S NO. 2 MILL.

Mark on pillar.	Sketch showing dimensions and manner in which load was applied. Inclination of bearings greatly exaggerated in sketch. Actual inclination 1 in 24. Sketches not drawn to scale. The shaded lines represent the rigid platforms of testing machine	Total length	Diam. at extreme top.	Diam. at A. B. 1½ inch from top.	Diam. at middle	Diam. at base	Diam. at principal rupture. Inches.	Area at principal rupture. Sq. in	Area at top at A. B.	Load at which snapping sounds were first noticed.	Deflections under this load (inches). Hor.	Vert.	Last defl. observed prior to rupture (inches). Hor.	Vert.	Load under which this deflection occurred.	Load that produced rupture.	Ultimate compressive str'ngth lbs., per sq. inch on area A. B.	Ultimate compressive str'ngth lbs., per sq. in. on area of pillar at section of rupture.		Abstract of notes made during the test.
No 16	Slightly Crooked, concave ½" No 16.	10 ft. 4¾ in.	5.82 in.	6.37 in.	6.95 in	7.78 in.	6 65	34 73	31 87	70,000	+ .03	+ .15	.05	.79	140,000	142,600	4,455	4,088	End bearings full and square.	Ends squared up in lathe and brought to an even bearing in machine. Failed by crushing at a few knots about ⅝ in. to 1¼ in. diam. 32 in. from top. This wood a little coarser grain than others tested.
No 9	Same as No 16, crook ¼ inch	10 ft. 4 in.	5.85 in.	5.88 in.	6.69 in.	7.49 in.	6 28	30 97	27 15	100,000	+ .17	+ .19	+ .42	+ .42	175,000	192,800	7,100	6,225	Average, 5,071	Ends squared up and set with full bearing. Pillars, as a whole, rather free of knots. Upper portion contained 5 season cracks open from ⅛ to 1-32 in., and extending two-thirds the way to the centre. Grain spiral—numerous spiral season cracks 1⅛ in. twist per foot run led me to expect this would prove one of the poorest of the lot. Failed by crushing and splintering at a 1-in. knot.
No 3	Same as No. 16. Cap bears on lower edge at start, and is off 0.07 in. at upper edge. Base bears at top. Base off 0.11 in. at bottom	10 ft. 5¾ in.	5.85 in.	6.40 in.	7.20 in.	7.74 in.	6 57	33 90	32 17	58,000						166,100	5,163	4,900		Under about 60,000 lbs. apparently came to full bearing on both ends. Nineteen rings of annual growth per inch. This pillar contains 35 knots, averaging ½ in. diam. Failed by numerous splits at some small knots 16 in. from top.
No 7	Concave ⅜" No 7.	10 ft. 5½ in.	5.70 in.	6.35 in.	7.02 in.	7.77 in.	6 7	35 26	31 67	20,000	— .02	— .44	— .31	1.69	105,000	108,200	3,416	3,070	End bearings inclined opposite.	Under 50,000 lbs. base came to bearing over half its area. Under 100,000 lbs. base has now come to bearing over nearly its whole area. Failed by a split opening through middle of upper half of pillar. On continuing load crack extends, and would split pillar into halves for its whole length. This split was mostly a fresh one originating with the application of this load. Knots evidently had little to do with rupture.
No 1	Tested in same way as No 7	10 ft. 5.1 in.	5.70 in.	6.26 in.	6.90 in.	7.70 in.	6 90	37 39	30 78	15,000	0	— .26	+ .13	— 1.78	105,000	105,000	3,411	2,811	2,944	This pillar is rather knotty. Failed by crushing at a cluster of small knots near centre, and also fibres pulled open on convex or opposite side. Base of pillar against the oblique bearing, though compressed a little, was not splintered at all like 12, 13 and 11 A.
No 2 B	No 2 B	10 ft. 5.2 in.	5.80 in.	6.22 in	6.81 in	7.61 in	6 36	31 77	30 39	30,000	0	.07	.46	— .50	168,000	168,000	5,528	5,288		First attempted to test pillar with both ends having sloping bearings as No. 7. Bottom of pillar began to split under 10,000 lbs., therefore removed wedge from bottom. An old season crack extending to centre runs whole length of pillar. Failed by crushing of fibres at 3 small knots ¼ in. diam. 15 in. from top.
No. 11 B	Same as above, but 10 in. shorter. See note. Perhaps this should be classed with Nos. 16, 9 and 3. Corner of base had previously been crushed in expt 11 A, and sawed off, leaving pillar square and true at base	9 ft. 7 in.	5.74 in.	6.47 in.	7.05 in.	7.81 in	6 60	34 21	32 88				+ .40	.55	194,100	194,100	5,903	5,674	5,481	This stick almost perfectly straight grain and almost entirely free of knots. A 3-16 in. season crack extends ¾ of whole length, and 1-16 crack extends ⅛ the way down from top. Failure apparently not due to knots or to original cracks. Failed by crushing of fibres at 15 in. and 30 in. from top. The cap pinched top of pillar very tightly, and very likely this pillar should be classed as having nearly a full bearing at both ends.
No 18	½" Concave No 18.	10 ft. 5.4 in	5.85 in.	6.60 in.	7.20 in.	7.90 in	7 20	40 72	34 21				.24	1.22	155,000	155,000	4,531	3,806		With 50,000 lbs. pillar came to full bearing at bottom, except for 1 in. from edge. Yielded by crushing on concave side at a knot in centre ⅝ in. diam.
No 12	Placed in machine with wedge bearings the same as No 7, but yielded by crushing corner of base	10 ft. 4.9 in.	5.82 in.	6.38 in.	6.91 in.	7.77 in.			31 97				.30	1.50	95,000	96,100				This pillar yielded by the gradual crushing of the corner in contact with the oblique bed plate. This "brooming up" of end induced cracks which gradually extended 4 ft. up the pillar.
No 13	Placed in machine with wedge bearings the same as No. 7	10 ft. 5⅜ in.	5.73 in.	6.38 in	6.98 in.	7.78 in.			31 97							125,000				This pillar yielded in manner similar to the last by the gradual crushing of the corner in contact with wedge at bottom, and this in turn gradually caused splits to extend up the post.
No 11 A	Placed in machine with wedge bearings the same as No. 18. For subsequent test of same pillar after cutting off end injured in this test see 11 B above	10 ft. 4⅜ in.	5.74 in.	6.47 in	7.05 in.	7.81 in.			32 88							60,000				This yielded in the same manner as the last two by gradual crushing and splintering of corner in contact with wedge at base. Began to crush at 10,000 lbs. Crushed to full contact with 60,000 lbs. pressure.

Linear elastic compression was also observed for No. 9 with a gauged length of 10 feet: For 50,000 lbs., compression = 0.0615 inches; set, 0.0011 inches. For 100,000 lbs., compression = .1215 inches; set, 0.0023 inches. For 150,000 lbs., compression = .1813 inches; set, .0028 inches. For 175,000 lbs., compression = .2100 inches; In all cases of oblique bearings the slope was ½ inch per foot. Average weight of these pillars was 83 pounds.

NOTES ON CIVIL ENGINEERING IN ENGLAND.

By Wm. H. Searles, Member of Civil Engineers' Club of Cleveland.

[Read Sept. 10, 1889.]

Liverpool, the grand gateway of the United Kingdom for the commerce and travel of America, greets its trans-Atlantic visitors at once by a magnificent display of engineering works. Its entire water front for a distance of nearly six miles is composed of a succession of massive masonry walls, articulated at intervals with heavy tidal gates, and inclosing broad basins or docks of sufficient area to accommodate easily all the world-wide snipping of the port.

The necessity for such docks arises from the great fluctuation of the tide in the Mersey, amounting to no less than 30 feet, and making it impossible for a ship to unload conveniently at an ordinary pier. The level of the water in some of the basins is kept at about half tide, in others at high tide, and the gates for entrance or exit of vessels are only opened when the water on the outside is at the same level as within.

The warrant for such expensive constructions is found in the enormous commerce of the place, a commerce which has rapidly increased during the present century, and which has by no means attained its limit as yet. These works exhibit the same qualities that characterize the engineering structures everywhere in England, massiveness, solidity, strength and permanence. They show a comparative disregard of first cost in the aim to make them economical of maintenance for all time to come.

The *Alexandra Dock* is of recent construction. It has a water area of 34 acres and can accommodate 22 Atlantic steamships at once, for which trade it was specially designed. The *Langton Graving Docks* adjoining are of double length, with middle gates. The powerful pumping engines of these docks are housed in a handsome and imposing building.

The *Canada Dock* accommodates the timber business, and has a large shipping yard connecting with the railways.

The *Waterloo Dock* is provided with large grain warehouses, the floors of which aggregate 12 acres, with a total capacity of 57,000 tons of grain, or over 2,000,000 bushels. The buildings are of stone, thoroughly fire-proof, and provided with ample elevators, carriers, screens, scales, etc. All the machinery is worked by hydraulic power under a pressure of 700 pounds per square inch.

The *Herculaneum Dock*, at the south end of the city, has, in addition to its large water space and three graving docks, a storage capacity for 60,000 barrels of petroleum in "casemates" tunneled into the rock and closed in front with walls of Portland cement concrete. Each casemate is capable of containing in bulk all the oil stored in it in barrels, should the latter burst in case of fire.

Liverpool was the first city in England to construct docks, the first dock having been built about 1712; but many other maritime cities of England have since been obliged to follow her example. At Birkenhead,

on the opposite bank of the Mersey, are several notable docks and basins, the largest of which is called "The Great Float."

A good foundation of either gravel or rock is found at a convenient depth and many of the walls are of concrete, with granite copings.

The Birkenhead docks have cost $30,000,000, and the Liverpool docks several times as much. Liverpool has now 54 docks and basins, covering 260 acres and giving nearly 19 miles of quay space.

The Mersey Tunnel is of recent construction, having been opened Jan. 13, 1885. It connects Liverpool and Birkenhead through sandstone rock under the river, which is three-quarters of a mile wide between the bulkheads on this line. The rock cover is 20 to 35 feet. The lowest rail level is 145 feet below mean high water. The grades are steep, 3.7 feet per 100. It is provided with two lines of rails, and is used at present for local traffic only, having about 300 trains a day. The largest number of passengers carried in one day is 52,000. The present terminus is at James street station, but the tunnel is to be continued another half mile to a central station, and will then be used by the Cheshire Railway to gain access to the heart of Liverpool. The tunnel has headings for both drainage and ventilation. The drainage headings extend to shafts on either side of the river, and the water is raised by pumps 170 feet. The ventilation gallery is parallel to the tunnel, and is connected with it by frequent openings which can be closed at pleasure.

Coal-burning locomotives of 70 tons each drag the trains, and it is customary to close the doors and windows of the carriages to keep out the gases during the trip. The tunnel is in darkness, but every compartment in the train has a lighted Pintsch lamp. The trip occupies about five minutes between the shafts on either side. In the shafts are placed hydraulic elevators capable of holding 100 passengers each, and making the lift of 100 feet in 40 seconds. At the foot of the shafts the tunnel is enlarged to give room for station platforms 400 feet long. The rock is self-supporting, but has been lined throughout with blue Staffordshire brick laid in cement, to prevent percolation of water.

The engineers in chief are Sir Douglas Fox and Sir James Brunlees, assisted by Mr. Francis Fox, who has special charge of the pumping and ventilating systems.

The cost of the tunnel was not ascertained, but it has not been able to earn dividends in its incomplete condition.

THE MANCHESTER SHIP CANAL is by far the most important and interesting piece of engineering work in progress in England at the present time.

Manchester lies 30 miles from Liverpool, in an air line a little north of east. The canal is 35 miles long, following the valley to the tidal lock at Eastham, on the Mersey, 5 miles south of Liverpool. The canal has four lift-locks, one of 15 feet lift, the othess of 13.5 feet. The lower level is 20 miles long. Each lock is to have three chambers side by side, the two largest being capable of taking large ocean steamers. The section of the canal gives 26 feet of water over a minimum bottom width of 120 feet, allowing the largest ships to pass each other at any point. The last 3½ miles near Manchester has a bottom width of 170 feet. All earth slopes within the canal prism will be protected with slope-walls 3 feet thick.

Immense basins or docks are constructing at Manchester, covering 152 acres and affording a quay frontage of $5\frac{1}{4}$ miles. These basins have a uniform depth of water of 26 feet. They are lined with retaining walls of mass concrete on a natural rock foundation. The walls are 26 feet high, 10 feet wide on top and 17 feet at the bottom. The face slope is 1 to 16. The concrete for the body of the wall is of one part Portland cement to seven parts of a natural ballast, found in the canal excavations. The ballast is washed by a jet of water to remove earthy matter, and mixed by hand shovels, turning over the concrete five times. Hand size stone are thrown into the mass after it is placed in the wall. The concrete for the face is mixed one to four, but without stone. The face plank being raised regularly by uniform stages gives the face the appearance of ashlar work. The earth is thoroughly rammed for a space of 10 feet back of the wall. The wall has a coping of granite finely finished for a rubbing course, and on this is built a wall eight feet high, faced with blue Staffordshire brick and coped with handsomely dressed Cornwall granite, with rounded corners. The mooring rings are countersunk in the face of the coping, so that ships' cables may slip over them, and are elaborately anchored with branching rods, built into the masonry.

Many of the concrete walls are built in trenches dug to the foundation (35 feet deep), leaving the excavation for the basin to be made at a later date. The basins adjoin an old baronial estate, and the work was much embarrassed for a time by the refusal of the late owner, Sir Humphrey de Trafford, to give the necessary right of way on any terms whatever. But upon his death the son, finding money more desirable than land, sold all that was required on condition that the company build a high stone masonry wall on the property line. The wall is completed in advance of the canal works, and safely incloses a few sheep and cattle.

While the canal follows the valleys of the Mersey and the Irwell it quite ignores those rivers, crossing and recrossing their innumerable windings with its direct or gently curving course. Moreover, as the canal is to be far deeper than the rivers, they will be obliterated on the completion of the canal for twenty miles from Manchester, the canal receiving all the water and the unused loops of the rivers being filled with waste excavation. At present the water flows in the old channel, the excavation being made in disconnected pits, so as not to cut the river banks. To keep these pits dry requires the pumping of 6,000,000 gallons of water daily.

Near Warrington there is a cut three miles long and from 50 to 60 feet deep, largely in red sandstone. The stone is not blasted, but quarried regularly, so that it may be used for masonry and paving elsewhere on the line of the canal. By this cut the line of canal is straightened, and the valuable town property in Warrington on the Mersey is avoided. A basin or branch canal leading to Warrington is provided for. Several railways cross the canal over this deep cut.

The entire canal was let in a single contract, and although the work is divided into eight sections for convenience of reference and estimate, it is not sublet, being more easily worked in its entirety by interchange of material from one section to another.

As a preliminary to the canal a railroad was built for the entire distance

by the contractor at his own expense, with numerous sidings, the total mileage of track being over 200 miles. On this road he has placed 4,000 cars dumping from the side, 1,500 cars dumping from the ends, and 1,000 others of different patterns, including one handsome parlor coach for the use of the directors and visitors. There are about 150 locomotives. The busy steam shovels along the line number over 80, and there are as many steam cranes, and nearly 200 pumping and other engines. The human force numbers about 12,000 men. To properly provide for the welfare of so many people the contractor has erected three hospitals, where sick or injured men receive the best of care. He has also provided libraries, a lyceum for lectures, and a church for the benefit of the working men, which is well attended. By these means added to fair wages he secures to himself the hearty allegiance and co-operation of all his men, and he has never had a strike among them. This contractor is Mr. Thos. A. Walker, an Englishman, who, however, began operations on our own shores by taking a contract on the Grand Trunk Railway in 1852. He was the contractor for the Severn Tunnel, 22,982 feet long, a work of prodigious difficulty begun in March, 1873, and completed in December, 1886. At the present time he is executing a contract for a breakwater and quay at Buenos Ayres, costing from five to six million pounds sterling. He values his entire contractor's plant at £3,000,000. He is a gentleman of medium size, with a singularly unassuming and modest manner and pleasant address for one commanding such great interests. He directs the work of the Manchester Ship Canal in person, and has no partners in the contract. What would become of the vast undertaking in the event of his sudden death, or who would efficiently manage his complicated estate, is a question impossible to answer.

The engineer of the canal is Mr. E. Leader Williams, C. E., to whom is due the original design and the overcoming of many seemingly insuperable difficulties and the solving of many intricate scientific problems, such as would naturally attend so great an undertaking in the midst of an old and thickly-settled country, traversed in every direction by established highways of traffic. He is a large, fine-looking man, with great force of character combined with suavity of manner.

For the last 50 years we have seen railroads take the precedence of all other means of communication in enforcing the right of eminent domain, choosing their location to suit themselves and making other interests bend to theirs. But now comes the ship canal and reverses all this. All the railroads crossing the proposed canal, including some of the most important in England, are compelled to change both location and grade, and to surmount an elevation of 75 feet clear of the water surface, in order to accommodate the shipping on the canal. This has not been accomplished without a tremendous struggle, lasting for years, but ending in a complete victory for the canal.

Not thus could the old canal interests be set aside. The Bridgewater Canal, although of small section and floating canoe-like barges, could not be raised nor lowered, nor yet abandoned, for its traffic is very important. It crosses the Irwell, at a moderate elevation, by the famous and now venerable aqueduct built by James Brindley, the great canal engineer of the last century. True, the old aqueduct, with its ivy-clad arches, must

be destroyed, but before this can be done a new one alongside of it will be constructed with a central span of iron or steel, capable not only of being swung to pass the traffic of the ship canal, but also of being lowered and raised on its central and piston-like support, so that the canal barges may be transferred at pleasure from one canal to the other. The designs for this most modern of aqueducts, as well as for all the other structures of the canal, are by the engineer, Mr. Williams.

The lower 13 miles of the canal are directly along the bank of the Mersey, an arrangement which, though costly, was determined upon after a great amount of study, as preferable to deepening the channel of the estuary by jetties, etc., for the same distance.

The total excavation for the canal exceeds 44,000,000 cubic yards. The contract was let January, 1888, and is required to be completed by January 1, 1892, under a penalty of £500 a day for delay after that time, and a premium of the same amount for earlier completion. This requires the removal of material at the rate of 1,000,000 cubic yards a month: but the contractor has been able to exceed this average considerably. The contract for the canal proper is for the sum of £4,500,000, and the contractor is to take £500,000 of this in stock. The total cost, including terminal facilities, is estimated at £5,750,000. The right of way has cost over £1,750,000. The authorized stock of the company is £8,000,000, with power to borrow £1,812,000. The expenses during the years of incubation, before the parliamentary powers necessary to success were obtained, were very great, and the delays almost disheartening. There seems now to be no doubt of the completion of this enterprise at the appointed time, and Manchester may then boast of one of the finest marine highways in the world.

It is estimated that one-third of the tonnage arriving at Liverpool will pass up the canal without breaking bulk.

A SKEW BRIDGE at Rugby was noticed, that is a curiosity in its way. It is composed of two girders 75 feet long, while the clear opening is only 12 feet measured at right angles to the abutments, consequently the skew angle is about 80 degrees, and as the girders are about 12 feet apart in the clear, the girders do not lap by each other at all, but one may be said to begin where the other ends. Consequently they do not afford each other any lateral support, and every floor beam has one end resting on an abutment. The girders are two feet wide by seven feet high, triple intersection, composed of channel and plate irons, riveted. The floor beams stand upon the lower chord, and are riveted to the girder in a substantial manner, and all the work being heavy, the bridge does not appear insecure, although of such unusual design. It is used for the crossing of one single-track railway over another. The abutments are of hard-burned brick, as is not uncommon on English railways.

THE FORTH BRIDGE, though in *Scotland*, near Edinburgh, may be mentioned under the title of "Civil Engineering in *England*," without committing an *Irish* bull, inasmuch as it was designed by and built under the direction of two most distinguished English engineers, Sir John Fowler and Mr. Benj. Baker, of London.

It will not be possible here to give even an outline description of this

latest wonder in bridge construction, nor is it necessary, since its plan and progress are duly published in the technical journals.

The first impression made on the mind by a sight of the three huge cantilevers, now nearly completed, is that of a solemn procession of elephants, ungainly, cumbrous and useless. They stand tandem in the Forth, disconnected from each other and from the approaches, yet reaching out toward one another, each with a magnificent stretch of one-third of a mile from tip to tip, balanced over a central support. Seen at a distance, their great size does not fully impress one, but they grow on the sense by a nearer approach, until everything else is dwarfed by comparison. The approaches, which elsewhere would figure as grand viaducts, here scarce claim attention. Yet they are composed of piers 150 feet high and 168 feet apart, five spans on the south and ten on the north side of the Frith.

The bridge is a special one in all particulars, in design and in execution, in the yard and shops prepared exclusively for its manufacture, and in the machines invented for manipulating and preparing the plates and connections—ponderous machines which are only thrown upon the scrap heap, many of them, when their office in connection with this particular bridge is accomplished. To this yard the plates are brought direct from the mill, and all the work necessary to fit them for their place in the great structure is done on the spot. All sheared edges are afterward planed, all holes drilled, all peculiar shapes and bends given by hydraulic presses and dies, the plates being red hot, and finally a careful annealing is given. Then comes the assembling in the yard, all parts being accurately and positively fitted together before they are allowed to go out of the yard. After assembling, the parts are taken down, floated out to the bridge and hoisted separately to their place in the structure. One of the connecting or central spans, 350 feet in length, was being assembled on July 2d last at the time of the writer's visit. To allow for expansion and oscillation one end of this span is to be supported by its upper chords resting on vertical posts standing on the lower chord of the cantilever arms. The posts have spherical ends fitting into sockets, allowing them to rock freely. The motion is suitably checked by other devices.

The tubes forming the main posts of the cantilevers are 12 feet in diameter: the lower chords at the base are of the same size, and where these meet each other and the somewhat smaller main braces, making five cylinders in all at a common point, some very queer intersections and details of riveting may be seen. The steel cover-plates for these joints have been tortured into extraordinary shapes.

At present a timber pier extends from the south bank to the first cantilever foundation, and here a steam lift gives access to the level of the roadway 160 feet above the water. The boldness of a truss extending out over the water for 600 or 700 feet unsupported is more apparent now than it will be when the central span is in place and the roadway continuous, although, of course, the strains will be much greater then than now.

The resistance to wind, however, is quite as important as any other. The wind pressure on a truss 340 deep and 1,700 feet long, figured at 56 pounds to the square foot, is something respectable. It is estimated at 7,900 tons on one of the main spans, while the practical train load on double track for the same span is only 800 tons in all, or only about one-

tenth of the wind pressure at 56 pounds. The weight of steel in the cantilever portion of the bridge is about 42,000 tons, and in the fifteen approach spans 3,000 tons, or 45,000 tons in all. The piers contain 120,000 cubic yards of masonry. The piers are faced with Aberdeen granite. The approaches on either side begin with three 25-foot arches in granite ashlar, most beautifully dressed and finished.

The whole structure impresses one with a sense of its prodigious strength, an impression fully verified by the engineer's figures; but there comes, also, an astonishment at the cost of such a work and a wonder as to what should justify such an expenditure at that place. The roads that will use the bridge already have rail connection by a detour of a few miles. There was probably a stimulus in the shape of competition with roads running direct on the west side of the island which led to this gigantic undertaking, combined with the hope of some little pecuniary gain in the saving of distance and grade.

The contract for the superstructure is understood to be for the sum of £1,600,000, but what the total cost of the bridge will be, with its deep foundations and innumerable incidental expenses, we must await the issue of a final report to ascertain. The contractor's plant is valued at over £250,000.

But whatever may be the financial exhibit, this bridge, one and a half miles in length, carrying a double track railway at an elevation of 160 feet above high water, across a tempestuous arm of the sea, in clear spans of 1,710 feet, and over channels 200 feet deep, marks an era in the advance of engineering science, and will be a grand monument to the commercial enterprise and professional skill for which the closing years of the nineteenth century are already so justly noted.

DISCUSSION.

Mr. Leland: What is the annual tonnage of the port of Liverpool?

Mr. Searles: I stated incidentally, as a remark outside of the paper, that the tonnage of Liverpool was about 4,000,000 per annum; that was the tonnage in one direction only. For 1886 Liverpool had entrances to the amount of 5,017,000 tons and clearances to the amount of 4,714,000 tons; this is with cargoes and ballast. Exclusive of coasting vessels the foreign trade altogether would make a little over 10,000,000 tons in 1886. Looking back over preceding years the increase in tonnage does not appear to be rapid, and probably there is very little difference at this day.

Mr. Bowler: I was interested to know how they fixed the foundation for the sea wall. I thought the water was not very deep, and I wondered that the waves and tide coming in did not wash it out.

Mr. Searles: At Liverpool there is no sea because it is an estuary, and the wall is thoroughly protected. So there is no occasion for anything but a mere reservoir wall to retain the water in basins when the tide is below them.

Mr. Porter: If I understand rightly, these docks are enclosed like a dry-dock, so that the water in the basins can be kept up to a uniform height. Are the pumps arranged so as to pump water both in and out?

Mr. Searles: The docks intended for very large steamers are kept about high tide level, and consequently the Atlantic steamers can only enter the docks at high tide and leave them at high tide. The pumping engines are used, as I understand, mainly for the purpose of clearing the dry-docks, and, of course, incidentally, they may be used for correcting the level of the basins if necessary.

Some other basins are kept only at half tide, and, consequently, can be opened twice as often. In some cases there are only single gates between the river and the basins; in other cases there are double gates like our canal locks, and a chamber in which the vessel may ride while the water is being raised or lowered.

Mr. Porter: How do the docks at London compare with those at Liverpool?

Mr. Searles: I did not make a special visit to the docks at London. As I understand the matter from drawings and what I have read, I think the docks are very similar in general idea, while there may be a difference in shape and dimensions. They are built very much by the same engineers and for the same general purposes. The London docks, in some cases, are on a neck of land, so that they have outlets at both ends into the river.

Mr, Whitelaw: Do the docks seem to have communication with each other?

Mr. Searles: Docks of the same group and name only are connected.

Mr. Whitelaw: Is the masonry all of blocks of concrete?

Mr. Searles: The early docks were built of masonry. The modern ones are made of concrete. They have the advantage there of a very good foundation at a reasonable depth.

Mr. Swasey: From the way in which they were constructed they seem to be built for ages, and not for a few years. I think one little remark made by the Superintendent shows the manner of the whole construction of the Liverpool docks. There happened to be a little group of us in a room where there was an engine of about 18-inch cylinder. It was running very slowly—I presume it was making thirty strokes per minute—and the Superintendent, knowing that we, as Americans, run engines very much faster, said: "That will do a vast amount of work in twenty years." And this seemed to be the key to the whole situation, for the way in which everything around there was constructed was not only for a few years, but for hundreds of years.

Mr. Porter: How do you think the crossing under the river compares with a crossing over it?

Mr. Searles: I think it would have been impossible to go over and give the necessary head-room to the ships. The terminals of the tunnel are right in the heart of the city, not at any great elevation above the water. I understand that at the terminals proper they may have no elevator at all The elevators are near the water and are for the convenience of those who wish to visit the streets near the water front, while the terminal proper projected on the Liverpool side, allows the road to rise by a steep grade to the basement depot.

Mr. Mordecai: Are those docks or any one of the docks set apart for any special class of freight, or do all classes of freight come into them?

Mr. Searles: The docks at the north end are used entirely for the trans-Atlantic steamers with promiscuous freight. Near the north end are the lumber docks.

I do not think that each road has its own tracks there, but all the roads enjoy access to the docks for lumber.

Mr. Porter: Have they special arrangement for unloading livestock? I understand that there is something like a floating bridge and a platform going out some distance.

Mr. Searles: These have no connection with the docks; that is, they are floating stages on the river, of large dimensions.

The landing stage for passengers and baggage is over 2,000 feet long and 80 feet wide, and is connected with the mainland by seven bridges, somewhat similar to the bridges used at the ferries in New York, except that they may be four times as long, so as to accommodate the change of tide. It extends several blocks along the city front.

I did not see any grain coming from vessels. The grain warehouses are inside the docks, of course, and there the grain is taken into the buildings.

The elevators are something like certain ones in Buffalo. They are six or eight stories in height. The grain is stored on every floor, and transferred from bin to bin on carriers—not very different from some of our modern dock grain warehouses at the Atlantic docks; but all perfectly fire-proof. These English buildings are like all their other work—perfectly solid and fire-proof in every particular. They are made available for both grain and ordinary goods on different floors. They are capable of storing a couple of millions of bushels or more.

Mr. Barber: Referring to the floating docks; of what are they made?

Mr. Searles: They seem to be made of wood in one solid construction right along.

Mr. Whitelaw: Did you learn anything of the probable effect the Manchester Ship Canal would have toward getting the shipping away from Liverpool?

Mr. Searles: Yes; naturally, Liverpool is very much opposed to the canal, because she has grown rich on the commerce brought there, and largely in the rehandling of goods from ships to railways. It is now thought that one-third of all the tonnage that now comes to Liverpool will go direct by canal without breaking bulk and not touch Liverpool at all—a great loss in one sense to Liverpool. Every possible argument was made why the canal should not be built.

Mr. Whitelaw: Is it a private enterprise?

Mr. Searles: It is not a government enterprise. It is an enterprise of the citizens of Manchester; not a municipal one—not done by the city as such.

Mr. Whitelaw: I understood you to say that the bottom of the slopes were covered with masonry.

Mr. Searles: The earth slopes are walled about three feet thick: about one foot of smaller stone and two feet of heavy stone laid on it. It is walled all the way from the bottom to the top of the slope. There is a tide lock at the easterly end. The basins at Manchester are some 65 feet above mean tide. There are four locks which have a lift of about 13 to 15 feet, and, of course, the water to supply them comes from above in each case, and the tide lock is arranged to suit any stage of the river. There is a very large series of basins constructed at Manchester to hold a great deal of shipping and store a great deal of water. All the water does not come from the river Irwell, which is a small stream. A little way down the canal, the Mersey flows into it. The water of this larger stream and the water of the Irwell will all be stored so that it can be used in the lower locks; some shipping only coming up part way and returning to Liverpool without going to Manchester. These four locks are rather near together. The first level from the tide lock reaches over half the length of the canal. The others are distributed, and the last one is three miles or more from Manchester.

Mr. Barber: What becomes of the earth deposited?

Mr. Searles: They have had to buy great quantities of land on which to put spoil banks: when the canal is opened a good deal of it can be removed again and put into the old river beds.

Mr. Thompson: Did you see the plans of the locks for the canal? Will they be peculiar in their construction?

Mr. Searles: The locks are not built as yet; but the description of them is that they are built with three chambers, side by side, and one account says that two of them will be full size for the largest steamers, and the third one smaller.

Manchester is one of the largest cotton manufacturing cities in the world, and the rehandling of the cotton at Liverpool is quite a tax on the commodity. The ships that bring it there can, when the canal is finished, unload directly at the Manchester quays.

Mr. Mordecai: Is it merely for local traffic at Manchester that the canal is to be built, or will Manchester draw trade that now goes to Liverpool?

Mr. Searles: As I understand it, the canal is subservient to the manufacturing

interests of Manchester at the present time. It will save all tolls that are now paid to Liverpool. Of course there are other towns not far from Manchester which will share more or less the advantages of the canal; but Manchester will be the chief gainer, and she has supplied most of the money.

Mr. Palmer: What is the estimated cost?

Mr. Searles: I presume about £10,000,000, ultimately.

Mr. Barber: Is the Forth Bridge yet a long way from completion?

Mr. Searles: It is very near completion. It is to be opened next month and to be completed before the expiration of October.

Mr. Swasey: I was there the 2d of September and the engineer said that the spans would be connected in about three weeks, and that in five or six weeks the bridge would be ready for traffic. They had completed about fifty feet out at each end of the connecting spans.

Mr. Barber: Did it strike you that the forms of the materials used in the construction of the bridge (the forms of the columns and their connections with other portions of the bridge) were unnecessarily difficult in manufacture?

Mr. Searles: There is certainly an advantage in a cylinder in many ways, but in a complicated truss the intersections of the cylinders in riveted work give a good deal of difficulty and have rather a clumsy appearance to the eye.

Mr. Barber: If I recollect rightly that bridge is about 100 feet longer than the East River bridge in New York.

Mr. Searles: The spans are 1,710 feet each; the East River bridge has one span of 1,595.

Mr. Porter: Are they putting in connecting spans as continuations of the cantilevers?

Mr. Searles: Yes, sir. When the span is completed a disconnection will be made so as to leave a 350-foot span hanging from the cantilever arms.

The main columns of the cantilevers are 12 feet in diameter. They are 340 feet high.

Mr. Swasey: I was very much pleased with the intersection of the various compression members, which they call the "Skewback," where the plates were formed into such irregular shapes. Of course, it is a great deal more expensive than we would have made it in America, but it looked to me like a very excellent piece of work. Another thing that struck me was the simplicity of the structure, by which all the strains were concentrated to the comparatively small base.

Mr. Searles: I quite agree with Mr. Swasey in regard to the excellence of the workmanship. The only criticism I had to make was that such a case should occur, whereas, if rectangular shapes had been used more simple connections might have been made.

I understand that the bridge cost $15,000,000.

Mr. Mordecai: What is the commercial necessity for the bridge?

Mr. Porter: About as much as the commercial necessity for the bridge at St. Louis.

Mr. Searles: Geographically speaking, England and Scotland are the same territory, and this Frith of Forth is but a small gash extending into the side of the island. If England and Scotland were separated by a strait, then we could see why the bridge must be put there, no matter what it cost.

Mr. Swasey: Really the $15,000,000 does not seem to be high in comparison to the cost of the East River bridge.

Mr. Porter: The St. Louis bridge cost over $13,000,000.

ELECTRIC MOTORS AS APPLIED TO THE PROPULSION OF STREET CARS.

By Nathan S. Possons, Member of Civil Engineers' Club of Cleveland.

[Read October 8, 1889.]

The mere question of obtaining motive power from electricity is neither new nor startling: but it is only since the discovery of the means of economically producing powerful currents of electricity, that motion by this method becomes practicable. When currents of electricity were first utilized for practical purposes, and for many years after, the cost of generating them precluded their application to the production of motion. They were only used for metallurgical purposes and telegraphic signals, but by the discoveries and developments of the past few years the whole aspect has undergone a change. Scarcely fourteen years ago the principle of the dynamo-electric machine was placed at the disposal of the public. This principle immensely diminished the cost of producing current. By this principle the energy of coal could be evolved in the steam engine, thence conveyed to a distance and then reconverted into mechanical motion, or light, heat or other forms of active energy. The rate of progress thus far has been very rapid. Attention for a time was paid exclusively to electric lighting. Now, however, it is being utilized for transmission or distribution of power.

The first practical experience of the propelling power of electricity was by Dr. Siemens, who constructed a circular railway in Berlin in 1879. Its total length was 350 yards, its gauge 3 feet 3 inches, the rails being laid on wood sleepers in the ordinary manner, thus affording sufficient insulation to serve as a conductor for the current. Upon this railway four carriages were placed. On the first car was placed an electric motor. The axle of the motor was connected to axle of car, so as to impart its motion. A metallic brush attached to the motor collected the current from the conducting rail to the motor, thence through the return rail to the dynamo. Small as this railway was, it demonstrated its practicability. To-day the leading electrical savants are wrestling with the subject of propulsion of street cars. At best it is a disagreeable place to locate so finely constructed machinery as an electric motor, to receive the slush, the mud, the dust and dirt from a traveled thoroughfare. But its mechanical construction is such that it is made to stand the rough usage, and make its continuous trip.

The Fourth Avenue Street Railway Company in New York City, have designed a special car embodying all needed conveniences for the successful application of a storage battery system. The system of storage battery used is known as the Julien, and the car when fitted with its batteries and motors weighs about seven tons. The motors are connected to each axle of the car, and are known as 10 H. P. motors, the power being considered ample unless grades are excessive. The batteries are composed

of several hydrogen and oxygen plates to each battery, and are placed in trays under the car seats, and make a total of 108 cells. By an ingenious commutating device under the control of the driver, these can be readily connected so as to place the four sets in parallel, or two parallel and two series; or two parallel and three series, or all four in series, thus at starting giving each 54 volts, 108, 162 and 216 volts. The car starts easily with no jerk, and with a full battery cars run 25 miles. Batteries may be removed in eight or ten minutes, as they are arranged in convenient trays and quickly replaced. The cars absorb about one electric horse power per mile on this road, their speed being about nine miles per hour. They can be geared for greater speed, but the city ordinance has regulated this. The batteries have been in service for about six months, and the system is claimed to be practical, the cost of maintenance not exceeding that of horse power. The more level the road the cheaper the system. The advantage of this system is that it may be introduced side by side with the regular horse traction without great outlay, as the ordinary car may be altered to meet the system.

The systems now meeting with great favor and being generally adopted are known as the parallel and series system. These differ materially from the battery just described. A suitable generating station is placed in some convenient point on the line and the current generated is transmitted by suitable conductors along the line.

The parallel system has one overhead wire, or a wire leading over the centre of the track, returning to the generator by ground or through the rail. Where extremely long circuits are in use feeders or extra wires are run from the generating station, tapping the overhead wire at some distant point. The pressure of current used is about 500 volts.

In the series system the conductors are both placed overhead, feeding by one line and returning by the other.

There is still another system known as the underground conduits. This system comprises underground conductors, wherein the current from the generator enters one conductor, passes through the motor, returning through the second conductor placed in the same conduit. The current is picked up by brushes which are attached to a suitable arm, which passes through a slot in the top covering of a conduit. The conduit is provided with convenient and suitable connections with sewers to carry off surface water and accumulation of mud. The advantages claimed by this system are high efficiency and absence of overhead wires. Its disadvantages are great expense of insulation and danger to insulation of conductors and consequent increased expense of maintenance. The advantages gained by electric propulsion of cars are many. The public demand quicker transportation and the railroad company greater profits. Through the courtesy of Prof. S. H. Short I have been enabled to gather some data upon the cost of operating and maintenance.

The Huntington Railroad is run upon series system and is a Short line, being three and five-tenths miles, with a maximum grade of four per cent. connecting two thriving Virginian towns. The power station is equipped with a high speed automatic cut-off engine and a 50-horse power generator. The conductors are strung on two rows of poles with cross wires and have no ground returns.

Cost, based on running two cars 15 hours per day for thirty days—coal, 75 tons at $1.05	$78.75
Oil, 30 gallons at 22 cents	6.60
Two engineers	54.00
Two firemen	30.00

(The low prices paid for engineers and firemen are accounted for by the fact that the railroad was run in connection with a lighting station, and half time was charged to each.)

Three motor drivers	$75.00
Three conductors	112.50
Total	$355.85

The cost per car per day, including all expenses, drivers, conductors, etc., is $5.95. The cost per car per mile (10 miles per hour) is a fraction less than four cents (.03965). The cost of motive power alone is less than two cents (.018) per car per mile. As each car tows another when traffic is great, the actual cost is a trifle less. This road has run continuusly and successfully since its start, Dec. 15th last.

The Broadway line in St. Louis is also operated by the Short system. Its length of track is three miles, number of motor cars five, each carrying a trail. This plant is run by a 100 H. P. engine and with one generator. The system was placed upon an old roadbed with angles instead of curves, having all disadvantages of faulty construction, yet the cost of repairs has been practically nothing. No repair shop was needed, and the expert in charge and his assistant kept the electrical machinery in order. Very heavy thunder showers have been frequent. Lightning can strike the wires of a series system and be carried off by arresters placed within the station. With this system the cost of running cars with their trail is 3½ cents per hour per car, as we have data showing this to be the case.

The expenses at St. Louis are here shown for seven days' run. For 25 trains, two cars each—50 cars:

Eight linemen	$120.00
Two engineers	36.00
Four firemen	56.00
Two electricians	40.00
Four dynamo tenders	56.00
Oil, waste, etc	56.00
Total	$364.00
For one day	$52.00
Coal for one day—350 bushels at 7 cents per bushel	24.50
Incidentals	5.00
Extra men	6.00
Total cost of 50 cars one day	$87.50
Cost per car per day	1.75

The series system possesses many and varied advantages, its speed being regulated by the position of the brushes on the commutator, the speed of the motor being accelerated or decreased by the simple throw of the lever under the care of the driver. No power is wasted in resistances. The cars stop and start without jerk or jar, and the danger of a burn-out in the motor is seldom, if ever, experienced.

The parallel system has proved in some cities a failure, due, perhaps, to want of proper business management, while in others, as in our own

city, it is meeting with fair success. The power of the motors has been increased, the weak points fortified. The service is gradually improving, and when the rivalry in opposing lines becomes reconciled, we may hope for a successful motor service in our city.

The motors and fast running cars are very severe upon the track, and railway companies must understand at the outset that electrical equipment requires a heavier track than is required for horses. No doubt a better track for horses and mules would prove an advantage. The matter of a heavier track is something in which the public is interested, because, with increased speed and a smoother track, travel would be made more comfortable. The demand of the present is rapid transit, and to secure it we must have good track.

I have endeavored to get some data as to the comparative cost of operation of a parallel road as compared with horse traction, but have failed to get data I desired, as the change from horses to electricity has not as yet been fully consummated, and so much of the force has been engaged in repairing tracks, etc., that a comparison had not been made. I have been informed that the motor cars run 140 miles per day, while the cars propelled by horses ran 70 miles with five teams of horses, and that the motors are manipulated with one half-the number of men.

The motors attached to one car cost, each, $2,000, it requiring 10 teams to run cars same number of miles as motors, at a cost of $250 each team, $2,800. It is usual to allow 25 per cent. per annum for wear and tear of horses.

It may, therefore, be assumed that the electric motor and its utilization as a source of transmission of power has reached that stage of practical development from which it must necessarily advance, with a constantly widening circle of usefulness.

The day will come when horses for street car traffic will be as obsolete as the tallow dip, and in my opinion that day is not in the near future, but in the immediate future, for we see on every hand the steady growth of success. Invention after invention stands the test, after careful trial.

Hundreds of our brightest mechanical minds are studying this problem and each day marks some improvement in detail.

DISCUSSION.

Mr. C. O. Palmer: I would like to ask what the efficiency is of some of our electrical systems?

Mr. Possons: I think there is no question but that the "Series" has the greatest efficiency. It gives from 87 to 90 per cent. of the power that is put in.

Mr. Warner: What if an engine is developing 100 dynamic horse power?

Mr. Possons: The efficiency of the generator would be about 85 to 87 per cent. and the motor about the same.

Mr. Whitelaw: What would be the weight, in the overhead system, with wo motors on driving car? I understand that one of the objections is the extreme weight.

Mr. Possons: The general principle on which motors are built is to have about 100 pounds of weight per horse-power; so that 2,000 pounds would be he weight, in answer to your question. The storage battery, with its motor, about 9,000 pounds.

Mr. Mordecai: Does it require any more horse power to run a parallel than a series system?

Mr. Possons: It requires a great deal more power.

Mr. Force: The wire under the rail is simply to make the circuit better?

Mr. Possons: Yes, sir; to make it better.

Mr. Warner: When I was in Allegheny I inquired into the conduit system, and they told me there that the conduit system was about being abandoned. It was unsuccessful on account of the difficulty of insulation.

Mr. Possons: The series system runs with about 10 ampères of current and 25 volts to the horse power. With the ten horse power we therefore have 250 volts. The Huntington Railroad, to which I have referred, in West Virginia, has 15 horse-power motors, and they run with 375 volts for each motor.

Mr. Warner: What is the comparative efficiency of storage batteries? If the series or parallel systems utilize sixty or seventy-five per cent. from the engine, how does the other?

Mr. Possons: The storage battery is not as efficient as the motor. The losses in charging the storage battery must be taken into consideration. I assume that the efficiency of the storage battery would be about sixty per cent., whereas that of the motor and generator would be about seventy-five per cent.

Mr. Swasey: I heard a report that a horse went across the parallel system and dropped dead. Is there current so that a person would feel the shock more or less by putting the hands on the rails? My inquiry is, is it possible to get any injury from the track?

Mr. Possons: None whatever. In order to get a shock from either system you have to be in contact with both poles of the machine. If a person stood upon the track and held the overhead wire by the hand he would be shaken up considerably.

Mr. Mordecai: Would the shock kill?

Mr. Possons: That would depend upon the person.

Member: You say it is not possible for a horse or person to get a shock from the parallel system from standing on the rails?

Mr. Possons: Not possible, if the line is properly constructed. A gentleman explained to me to-night coming down on the car that he noticed last Saturday night, on Superior street, a horse car in the rear of a motor car and that the wheels of the horse car gave off as much spark as the motor did ahead of it. The explanation given was that the rails were not properly connected together.

Member: I noticed at one power-house in the city that they were very careful not to start the motor up until the horse car was away one hundred feet or so.

Mr. Searles: The current is supposed to return through the rail. Suppose one joint is defective and a horse in traveling the street should have a fore-foot on one rail and a hind foot on another rail, before and after the defective joint, would he not receive the current through his body.

Mr. Possons: I do not think he would.

Mr. Searles: I will restate my question. We understand that the return current, as we have it here in the streets, passes into the rail; that the joints are connected by copper wire to increase the conductivity. But I made a supposition that the joint was defective, and that a horse has a fore-foot on one rail and a hindfoot on another, with the defective joint under his body, would not some of the current pass through the body of the horse, the horse helping to repair the supposed break in that joint?

Mr. Possons: If the iron is a better conductor than the horse the electricity will follow the iron.

Mr. Warner: The same conditions would be in force if we broke the overhead wire and took hold with both hands.

Mr. Searles: That would be too strong a case. My own idea is that there is no danger in the case supposed.

The President: I notice that we have Col. Wm. H. Paine, of New York, with us, and would be glad to hear remarks from him.

Col. Paine: I am a learner on the subject and not a teacher. I came here to be instructed and not to instruct. I have been endeavoring to pick up information in regard to propelling cars on roads as an engineer of wider practice than being attached to one particular system. There are so many items necessarily involved in the subject that it is scarcely fair in me as an engineer to say that cables can be cut off by the yard and employed anywhere. We use cables on vertical railways—our elevators. Electricity does best on level roads. When we compare the two it should be made somewhere on an incline. There are also other questions to come up between the two—the volume of travel, etc. There are many different things that need to be discussed—that need to be carefully and intelligently studied—before it is determined what manner of motive power is to be used. I will say in regard to the cable on the Brooklyn Bridge that it is to-day doing more service than any known one mile in the world. Every road is to be studied by itself, and I cannot draw a general comparison as to the advantages of the two methods. Some one asks me the question: Do you prefer a cable road to an electric road? I cannot answer the question; it simply applies to some particular road. I illustrate my remark something like this: A young student entered one of our large steel manufactories. He asked an engineer in regard to some particular points, and was answered, "Had you come here fourteen years ago, when I came here, I could have answered you, but now I cannot."

Mr. Walker: What experimental data has Mr. Possons in regard to electric roads? I understand that there is a claim of seventy-five per cent. of efficiency. It seems to me that if seventy per cent. can be got it is very much. When we indicate an engine and say it develops so many horse power, and we propel a car, and that car is a certain weight with its passengers and dynamo, then have we got what is claimed? I do not think the additional dead weight of a car is taken into account in any of these calculations.

Mr. Possons: Is the road you suppose a series or a parallel system?

Mr. Walker: Series.

Mr. Possons: I think I am safe in saying that the road will develop seventy-five per cent. of efficiency.

Mr. Walker: I understand that the useful effect of seventy-five per cent. is taken in any kind of electrical machinery?

Mr. Possons: No sir; not any kind.

Mr. Mordecai: What efficiency do you get from a cable road?

Mr. Walker: Recent improvements in machinery operating cable roads have made some wonderful changes. The useful effect formerly on cable roads was only about from sixty to sixty-five per cent. The recent improvements have done a great deal toward making the efficiency much greater—about seventy-five per cent.

Professor Short: What we mean by the efficiency of the motor is the amount of power it will deliver as compared with that which the steam engine is giving at a given time? There is a place for the cable and a place for the electric roads.

Col. Paine: I cannot understand how people can draw any line between electricity and the cable on the broad question. When the Tenth Avenue cable line was laid in New York, it took 57 horse power to move the heavy machinery that was in the building. To run that one line of cable took 50 horse power. When we consider these figures we ask what is the percentage of the 107 horse power? Our cars were extremely large and it took 4 horse power for every one of the 87 cars run on that line. Now, these figures give me 318 horse power for the 87 cars, and there are 107 to be added on account of machinery and cable—what is the proportion between the cable and cars? It is some 325 per cent. I cannot understand the figures given on this subject.

Mr. Searles: It has been said that the object is to please the public by rapid transit, among other things; but we have not seen much rapid transit in Cleveland. The question I want to ask is, of what speed are the electric cars capable, the city ordinance out of the question? I timed a car from Collamer to the Public square, a distance of eight miles, and we were just one hour, and that was a usual run. There were no detentions.

Mr. Possons: The usual limit of speed is about ten miles per hour. The motors may be geared to any speed. The travel of gear is limited. With motor cars on our lines, here in the city, I understand that they run from twenty to twenty-four hundred revolutions per minute. I do not think it would be safe to travel much faster than this and expect to have the gears last any length of time.

Mr. Warner: There would be no objection to running faster were it not objected to by the city.

Mr. Force: Have there been no experiments made in regard to using different materials for those rapid-running gears—such as cast iron or a combination of steel with something else?

Mr. Possons: In explanation I would say that we have tried several combinations. The object in the main is to avoid noise. The most successful gear used up to the present time is a combination of rawhide and steel.

Mr. Swasey: They use in Cleveland a vulcanized rubber pinion. It makes very little noise and makes a very good pinion.

Member: We experimented a good deal on what we should use for a pinion, and in the first place tried rawhide. Then we tried the vulcanized fibre, which, the last I heard of it, was the best yet found.

[*Adjourned.*]

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

BOSTON SOCIETY OF CIVIL ENGINEERS.

October 16, 1889.—A regular meeting was held at Elks Building, 24 Hayward place, Boston, at 19:40 o'clock, President FitzGerald in the chair. Fifty members and twelve visitors present.

The record of the last meeting was read and approved.

Messrs. Francis W. Dean, Burton R. Felton and George I. Leland were elected members of the Society.

The following were proposed for membership: George M. Farley, Boston, recommended by L. B. Bidwell and H. C. Keith; and Lewis M. Hastings, Cambridge, recommended by G. A. Kimball and Hiram Nevons.

On motion of Mr. Howe, the Secretary was directed to convey the thanks of the Society to the following persons for courtesies shown the members and their friends on the occasion of the visit to the New Capitol at Albany, N. Y.: John Bogart, State Engineer and Surveyor; John P. Masterson, Chief Clerk, State Engineer's Department; Edwin K. Burnham, Superintendent of Public Buildings, and Isaac G. Perry, Commissioner of New Capitol.

On behalf of the Committee appointed to confer with a Committee of the American Society of Civil Engineers, Mr. F. Brooks informally reported that the Committee had written a letter to Mr. Shinn. the Chairman of the American Society Committee. The letter quoted the formal resolutions adopted by the Boston Society, December 15, 1886, and Oct. 19, 1887 (and printed in the Journal of the Association, Vol. VI., pages 116 and 435). The letter said further:

"As an illustration, suppose that the Am. Soc. C. E. should join the Association of Engineering Societies, and thereby have a majority of votes in its Board of Management, being entitled to thirteen managers, while of the eleven present Managers four are members Am. Soc. C. E., as is also the Secretary of the Board. In that case we believe the Boston Society would most willingly facilitate any changes in the organization which might be found desirable on account of the increase in its constituency.

"If the foregoing be an unreasonable supposition, we equally believe that any other plan which appeared well adapted to bring about the same co-operation of societies would be readily acceded to by the Boston Society.

"Besides the dissemination of ordinary engineering literature, there is an especial advantage to be gained by this intercommunication between societies in the case of subjects naturally requiring combined action throughout the country, as the establishment of uniformity in professional practice and of standards of various kinds. This was very clearly and forcibly stated in the report presented in the Engineers' Club of St. Louis, March 6, 1889 (see Journal of the Association of Engineering Societies, Vol. VIII., pages 229-30), by a committee on Closer Union of Engineering Societies; also in the address delivered Dec. 21, 1887, before the same club (see Journal, Vol. VII., pages 27-28), by the retiring President, William B. Potter; and it is illustrated by a statement appended to this letter about the work of a dozen of the committees of the American Society of Civil Engineers."

Mr. Brooks also stated that an acknowledgement of this communication had been received from Mr. Shinn, who wrote: "Our committee is very desirous of finding some method by which the moral and psychical force of the American Society and the various local societies can be made to operate as nearly a unit as possible;" and also stated that an extension might probably be secured of the time in which the American Society Committee could consider the matter before it.

On motion of Mr. Rice, the report was accepted, and its consideration assigned to the next meeting.

Mr. Stearns reported, for the committee appointed for that purpose, a draft of a new constitution and by-laws. The report was accepted, and it was voted that when this meeting adjourn, it be to the 30th of October, and that the consideration of the new constitution and by-laws be specially assigned to that time.

On motion of Mr. Sidney Smith it was voted, That the Board of Government consider the desirability of employing an able stenographer, that we may have reports of the discussions at our meetings.

The literary entertainment of the meeting consisted of personal narratives by members who visited Europe during the past summer.

The Secretary read letters from Mr. E. D. Leavitt and Mr. G. H. Barrus, describing interesting engineering works seen by them. Mr. Leavitt spoke of sound solid steel castings of 50 tons weight and others of the most intricate description which he had seen cast. He also described the method of pouring large crucible steel ingots, weighing up to 85 tons, and employing 1,400 men in the operation. The large pumping machinery at Rotterdam and at Kladnow, in Bohemia, and the electric lighting plant in Berlin, were fully described.

Mr. Barrus gave an account of his visits to the engineering laboratories of the Steam Users' Association and of the Owens College, in Manchester; also to that of Professor Unwin, in London. He also described the steam engineering exhibit in the Paris Exposition.

Mr. J. R. Freeman first spoke of the unbounded good will and hospitality showered upon the party by the English engineers, and then referred to the great wealth of material for engineering study in England, and that after a hasty run through the continent, he felt that tenfold more than any other country, England was the home of engineering and the place for an engineer on a tour of inspection abroad to put in four-fifths of all his time.

Of the Manchester ship canal, he felt that though a triumph of engineering skill, and perhaps, destined to prosper financially, yet its sole cause and hope lay in the extremely high freight charges of English railways and docks, and that a railway built, equipped and managed on the best American practice, if built by the side of the canal, could drive it into hopeless bankruptcy; and that it had here in America become so much the custom to growl at railway monopolies, that we failed to appreciate the wonderful cheapness and efficiency of a system which, notwithstanding high cost of labor, coal and iron, and smaller traffic, cost the merchant or manufacturer but about half the tariff common in England.

Mr. Freeman also spoke of the contracting engineer, common in England, but only beginning to be developed with us—the engineer who not only plans but executes the work as well. Speaking of the Forth Bridge as a far more grand and inspiring engineering work than the Eiffel tower, attention was called to the superior dignity given the former structure by the use of a few simple, gigantic steel tubes for members of the truss instead of a network of thin plates and angle irons.

In giving an account of brief inspections of some of the German technical

schools, Mr. Freeman spoke of the great superiority of the laboratory practice given the American student at the Boston Institute of Technology, for instance, and for which the world at large is indebted to our late Prof. William B. Rogers more than any other one man.

For profound mathematics or subtle specialties in chemistry, of course, the German school stands pre-eminent, but abroad the engineering laboratory or physical laboratory is primarily for the use of the professor in original research. In our Boston school it is primarily for the use of the student and for teaching him "finger wisdom."

In the magnificent palace recently erected for the imperial technical school at Berlin, the strong and far-sighted German government has shown a high estimate of the importance of technical education far superior to that as yet attained in the councils of our own commonwealth and nation. But in conversation with the speaker, the honored and able secretary of the English Institution of Civil Engineers said: "Technical schools! Why, I consider that right there, in Boston, you have the finest technical school in the world." In speaking of the ocean steamer as a triumph of engineering, and of his passage home on the "City of Paris," at the time she made her wonderful record, Mr. Freeman, among other comparisons, called attention to the fact that in the confined space of that one engine and boiler-room there was steadily developed, day after day, a power greater than the total water power of the Merrimack, at Lowell and Lawrence combined.

Mr. F. Brooks spoke briefly of a few of the more conspicuous features of the Paris Exposition, and read by title some notes upon less prominent topics which he proposed to offer for publication in the *Journal*. Mr. Brooks exhibited a number of photographs and other illustrations of the subjects treated in his remarks.

The meeting then adjourned to the 30th inst.

S. E. TINKHAM, Secretary.

OCTOBER 30, 1889: An adjourned meeting was held at the American House, Boston, at 19:45 o'clock, President FitzGerald in the chair. Forty-four members and three visitors present.

The President stated that the business before the meeting was the report of Committee on Revision of Constitution.

On motion of Mr. Stearns the Society resolved itself into a Committee of the Whole to take under consideration the draft of a new Constitution and By-Laws.

At 22:45 o'clock the Committee rose and reported progress. The meeting was then adjourned. S. E. TINKHAM, Secretary.

ENGINEERS' CLUB OF ST. LOUIS.

OCTOBER 9, 1889:—311th Meeting.—The club met at Washington University at 8:05 P. M. President Meier in the chair, twenty one members and three visitors present. The minutes of the 310th meeting were read and approved. The executive committee reported the doing of its 79th meeting, approving for membership, H. M. Kebby. He was balloted for and elected. The secretary announced an application for membership from John Dean. civil engineer and contractor, indorsed by Otto Schmitz and Charles I. Brown, which was referred to the executive committee. The secretary reported that investigation had shown that the acceptance of the proposal from the St. Louis public library would require the taking out of duplicate life memberships by twenty-two members.

After discussion by Messrs. Meier, Seddon, Eayrs, Moore, Bryan and Thatcher,

it was on vote ordered that final discussion of this matter be made the special order for the next meeting.

President Meier here called Prof. Nipher to the chair, and presented a discussion of a new tractor recently invented by H. L. Van Zile, an engineer of Albany, New York. The invention had resulted from certain mathmetical investigations, and rendered it possible to make the total power, or pulling force, available for traction. A model had been made, which easily mounted a 20 per cent. grade, while the same model, without the improvement, could ascend only a 10 per cent. grade. In the discussion, Robert Moore called attention to the similarity of this device to the Fell tractor, which was in successful use on the Summit Railway, over Mount Cenis. Prof. Gale spoke of the probable advantages this motor would have for street railway work, where the grades were serious, and where objections existed to the use of other forms of tractors.

Mr. C. H. Sharman then read a paper on "Some Reminiscences Connected with the Construction of the Union Pacific Railroad." Mr. Sharman entered the engineering department of this road in 1866 as rod-man, and remained on the work in various capacities until the completion of the road in 1869, when he held the position of division engineer. A graphic description was given of the difficulties met with in engineering construction at that day at points remote from civilization. Considerable interesting engineering data was presented, but the paper in general deviated somewhat from the strictly technical papers usually presented, being of a more popular and entertaining character. The applause which was given the author showed that the paper was fully appreciated.

[*Adjourned.*] WM. H. BRYAN, Secretary.

312TH MEETING, October 23, 1889.—The club met at the Washington University at 8:10 P. M., President Meier in the chair; twenty-eight members and two visitors present. The minutes of the 311th meeting were read and approved. The executive committee reported the doings of its 80th meeting, recommending John Dean for election to membership. He was balloted for and elected. The secretary announced an application for membership from Western R. Bascome, head draughtsman in the bridge department of the city of St. Louis, endorsed by A. H. Zeller and J. A. Laird; referred to the executive committee.

The secretary read a letter from the chairman of the board of managers of the Association of Engineering Societies, proposing a meeting of the board to consider the question of proposed affiliation with the American Society of Civil Engineers. Prof. Johnson stated that this announcement was made for the club's information, in order that an opportunity might be given the club to instruct its members of the board regarding some plan of united action.

Mr. H. A. Wheeler then presented some notes regarding the recent European trip of the American engineers. Some three hundred members of the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the Institute of Mining Engineers took part. Mr. Wheeler gave full particulars of the trip, beginning with the origin of the idea, and describing the places of interest visited, the banquets given them, particularly the one in Guild Hall, the ascent of the Eiffel Tower, together with some particulars regarding the interesting works that were visited.

The special order of the day was then taken up, being the final discussion of the proposition from the Public Library regarding permanent meeting place, library memberships and general co-operation. The subject was thoroughly discussed, those participating being Messrs. Robert Moore, Holman, J. A. Seddon, J. B. Johnson, Hubbard, Chas. W. Melcher, R. E. McMath,

W. H. Bryan and Russell. It was then voted to lay the matter on the table.

Mr. Seddon moved that a committee of three be appointed by the chair to look into the question of a room for the club's use and report at the next meeting, and that the club continue to meet at Washington University until other arrangements were made. Seconded and carried. The President appointed J. A. Seddon, J. B. Johnson and Chas. W. Melcher such committee.

Mr. Johnson exhibited a test piece of iron, which had been welded by the electrical process at the exposition, after which the meeting adjourned.

WM. H. BRYAN, Secretary.

313TH MEETING. NOVEMBER 6, 1889.—The Club met at the Washington University at 8:10 P. M., President Meier in the chair; thirty-two Members and five visitors present. The minutes of the 312th meeting were read and approved. The Executive Committee reported the doings of its seventy-sixth meeting, approving the application for Membership of Western R. Bascome. He was balloted for and elected. The Secretary then read the following report:

The committee on permanent location of the Engineers' Club have to report that out of a number of possible locations examined they regard the following as offering decidedly the best inducement for the Club's acceptance: To rent a room in the Laclede building, 16 by 22, for general headquarters, library and reading room. This room, adjoining the office of Messrs. Johnson & Flad, can be gotten for $20 per month, and can be suitably furnished by funds now in the hands of the treasurer. Also, Prof. Johnson, having charge of the index department, has agreed to leave the exchanges in the room for the general benefit of the Club, and as librarian to keep the room open for the issue of books to 6 P. M. In the same building, as a place of meeting, the Elks' Club room may be obtained, and while the committee has not yet been able to obtain final terms from the board of directors they are satisfied that they will be favorable.

[Signed] J. A. SEDDON, J. B. JOHNSON, C. W. MELCHER. } Committee.

After discussion by Messrs. Seddon, Gale, Wheeler, Hubbard and Holman, it was voted to adopt the report. The Executive Committee was, on vote, authorized to lease the room in question for one year, and to suitably furnish it.

Mr. Winthrop Bartlett then presented an informal paper on the "Olive Street Cable Road." The total length is 9.6 miles. The conduit is 39 inches deep; the Johnson rail, weighing 65 pounds to the yard, is used. The speaker gave the particulars of numerous details of construction. The road was built at the rate of 274.2 feet per day, counting every day between the time of starting and finishing. Interesting information on the subject of the horse power required under varying conditions of service was given. The enormous fluctuations of power were shown by an indicator card, in which the power varied from 136 horse power to 609 horse power within one minute. The percentage of power required to drive the cable only, as compared with the total power used, was about 50 per cent., much lower than on other roads. A number of practical points of experience were explained, with details of improvements that had been made. Messrs. Russell, Johnson, Seddon and Hubbard took part in the discussion of this paper. The hour being late, it was ordered that Professor Potter's paper on "Fuel Gas" be made the special order of the next meeting, Nov. 20.

It was moved and seconded that a committee of three be appointed by the

Chair to prepare an amendment of the constitution regarding associate membership. After discussion by Messrs. Seddon, Johnson, Russell, Moore and Holman, it was ordered that the motion be laid on the table.

[*Adjourned.*] WM. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

OCTOBER 2, 1889.—The 262d meeting of the Society was held at the Society's rooms, 78 La Salle street, at 7:30 P. M., with some sixty members present.

In the absence of the President, Mr. Benezette Williams, C. E., was called to the Chair, who at once suggested that a motion be made to waive the regular order of business. This being done, in appropriate words he introduced Mr. Cope Whitehouse to the Society, who, after thanking the meeting, entered at once into his subject for the evening. The following is an abstract of Mr. Whitehouse's paper under the head of:

"IRRIGATION IN EGYPT AND THE RAIJAN RESERVOIR."

Startling as has been the advance of the Western world in rapid transit of persons, merchandise and thought, the use made of water falling from the mountains to the sea shows no corresponding progress. The engineering works which here and there regulate the flow of a stream in the United States are contemptible in view of what remains to be done, and with scant exception are below the level of even the minor modern constructions to be found among those Oriental nations whom the American engineer has been often taught to despise. It has been an essential feature of that modern philosophy, which is popularly associated with the name of Darwin, that development is an attribute of time. The mechanical engineer in the presence of such stupendous triumphs as the ocean steamer, or the vast spans of many a bridge, may fearlessly challenge the past. It is, nevertheless, true that the unbridled career of our rivers, great and small, exhibits a barbarism so primitive that the founder of the Chinese Empire, who restrained the Hoang-Ho, or Menas, who established civilization in Memphis, building the city upon ground laid bare by the diversion of the Nile, would stand aghast at the sharp contrast offered by advancement in the use of steam, steel and electricity, with the utter neglect of that immense force that represented to the rulers of the East so obviously individual welfare and national empire. Those lords of the Nile would despise us as slaves of the Colorado and the Mississippi, contented to submit with supine tameness to the caprices of our water courses, as if these rivers were not as amenable to control as the drainage basins of the Abyssinian Mountains and the lakes of Central Africa. These questions of irrigation, drainage and river transportation are hourly assuming greater importance. They have attracted the attention of the American people. They are being carefully studied. The problems will be solved and the difficulties surmounted by that energy and febrile ingenuity which are characteristic of our country. It cannot but prove interesting and instructive to examine irrigation in Egypt, dependent upon that anomalous river which so long ago exercised human thought, and continues to this day to present the same conflict between nature and man.

At the commencement of this century French engineers succeeded, in supreme control, the Pharoahs, the Persians, the Greeks, and the Arabs. Now the ultimate direction is in the hands of about ten British officials trained in India. The native division engineers, however, are men of great local knowledge, and practical as well as technical ability. Ali Pasha

Mubarekh, now Minister of Public Instruction, was, when I first made his acquaintance, Minister of Public Works. He is a conspicuous example of success in amassing singularly vast stores of profound and varied knowledge on all subjects connected with the engineering profession.

The current idea of the topography of Egypt is erroneous in the extreme. It is not a sandy plain traversed by a river, whose inundation brings fertility to the farthest parts reached by the life-giving stream. The pyramids are neither in the river as Shakespeare says, nor in a sea of sand as Dr. Brugsch describes them. The Nile Valley, to the south of Cairo, is sharply distinguished from the Delta. The Nile itself is practically a double stream. The perennial flow is maintained from the great lakes of Equatorial Africa; the inundation is due to the rainfall on the Abyssinian mountains. The supply from the end of February, for about three months, is insufficient for the area under actual cultivation. This is little more than one-half the extent cultivated under the Pharaohs or the Ptolemies. The entire area of cultivated land is artificially irrigated. The inundation of Middle Egypt is everywhere controlled by embankments many thousand miles in extent. In upper Egypt, as soon as the water rises out of its deep channel, it is allowed to flow into districts of 50,000 to 80,000 acres. Should it afterward rise higher, it is excluded from these shallow pools, where the fertilizing alluvium is deposited, while the villages with their palm groves rise above the water like islands, each secured by its own wall of earth, strengthened by brick. The high Nile thus becomes a menace. Its flood is forced into a comparatively narrow channel, whose bounds it not infrequently bursts.

In the delta the inundation is wholly excluded whenever such summer crops as cotton, sugar-cane and rice are growing. Canals supply enough water for the crops. Scarcely one-twentieth of the whole discharge in flood is utilized.

The missing factor in Egyptian prosperity is the great lake Moeris, described by the ancient historians and depicted on their maps. The author's discovery of the Raijan Valley, which formed part of this reservoir, offers a means of controlling the flood waters of the Nile, and storing a sufficient portion of its surplus to double the discharge of the river during the annual drought. All the facts have been verified by the Egyptian Government, and reports have been made, based upon the official surveys by Sir C. C. Scott-Moncrieff, author of the well-known book on Irrigation, Under Secretary of State for Public Works; Colonel Western, the Director-General of Works; Colonel Ross, Inspector-General of Irrigation; Sir Edgar Vincent, late Financial Adviser to the Khedive; Nubar Pasha, late President of the Council; Colonel Ardagh, late Chief of Staff in the Army of Occupation, and many others. Lord Salisbury, Sir J. Ferguson and Sir Evelyn Baring have attested the accuracy of these reports and have conceded the enormous benefits which would accrue to Egypt from the execution of the proposed canal. The Khedive, with his strong love for the people under his care, has always manifested an appreciative sympathy for my investigations.

The Raijan project is briefly a scheme to put the Nile in communication with a depression, 250 square miles in area, in the desert to the west of the Nile and about seventy-five miles south of Cairo. Its circuit of 230 miles is bounded by plateaux of horizontal limestone, often rising to a height of 600 feet. Its soil is desert sand overlying rock and yellow clay. About one-tenth of the area is occupied by steep ridges of blown sand, sixty feet high. It contains no inhabitants. To the south are two springs, warm and sulphurous, with a few date palms and a little coarse vegetation. Its greatest depth is 153 feet below the Mediterranean, or about 250 feet below high Nile in the adjacent valley. It can be readily utilized to relieve the Nile during

flood, assist the drainage of Middle and Lower Egypt, and store water for summer use from April to July.

The shortest and most direct channel through the Berek-Aba-Hamed hill is six miles in length. This involves a tunnel or a cutting with a maximum height of 160 feet. A longer, but in many respects easier route, by the Myana pass is that which has been most fully considered. It has been surveyed with great care and thoroughness. It requires the handling of about 3,500,000 cubic yards of sand, clay and soft rock, with an average delivery of the materia' at 20 feet above the excavation. The same channel, with a regulator and flood gates, will be used for both the intake and outflow. The reservoir thus formed would contain about 20,500 million cubic metres, or say, 5,000,000 million gallons. The average rise of the Nile is about 25 feet. The stratum of water available without pumping would be 250 square miles by 25 feet, less evaporation and loss of head. This would yield an average annual supply of about 5,000 million cubic metres or say, 1,250,000 million gallons—equal to a daily delivery of 12,000 million gallons during the season of low Nile. The present minimum supply on which the whole export crop of Egypt depends—its cotton, rice and sugar-cane—is about 20 million cubic metres per diem, or less than one-half the amount which could be profitably employed. The Raijan reservoir would more than double the normal flow of the river at this season. The water is now economized in Upper and Middle Egypt as well as in the Delta. The demand for an increased quantity is immediate and pressing. On the completion of the system of Barrage canals it will require an increase of two-thirds of the present supply to cultivate the land which will be offered for summer cultivation. The total possible increased area of cultivated land has been officially put at 3,000,000 acres. The total volume of Egyptian produce would probably be nearly doubled. Sanitary questions have their economical aspect. The death rate now rises to 92 per 1,000—yet Alexandria was reputed in the Roman days to be the healthiest city on the Mediterranean, while the neighborhood of Cairo and Memphis was famed for its salubrity. The preservation from disaster is a material consideration. The loss by the excessive inundation has reached \$5,000,000, while the insufficient Nile last year was officially declared to have cost \$1,500,000.

It may, therefore, be safely stated that a reservoir and canal of escape can be contructed for \$2,500,000. It would not require more than one year to make the canal, and probably three inundations would suffice to fill the basin without prejudice to the interests of the present cultivated area. This represents an addition to the wealth of Egypt of not less than \$500,000,000 per annum.

The interest of this paper was enhanced by a series of lantern slides, chiefly from photographs taken by Mr. Cope Whitehouse. They included a series of maps of Egypt, from Papyri, Greek, Arabic and mediæval manuscripts, down to the map of the Egyptian Government, embodying his discoveries. These were followed by selected points of interest on the line of the canal, in the desert, or in that vast adjacent depression—the Fayoum—whose redemption has always been attributed to the Patriarch Joseph—son of Jacob—founder of the temporal prosperity of the Jewish nation, and reputed to have been the foremost engineer of ancient days. His dykes, canals and other works were shown to have remained in continuous operation down to the present day, on a scale of grandeur and with an element of persistence which prove the soundness of judgment as well as the boldness of conception of the engineer who designed and the government which executed them.

At the conclusion of the paper Mr. Whitehouse was questioned as to the

geology of the Nile and the basin he had discovered, to which he replied at length, stating that no satisfactory explanation had been afforded of the origin of the basin. He also further explained some of the physical conditions of the Nile.

Being asked as to any financial plan having been devised for carrying out the works, he stated that the money could be obtained without difficulty, but the impediments to immediate work were personal ones, in that an American layman had made the discovery and had pushed the enterprise in the face of a large array of engineering talent and official control. The details of this feature of the enterprise were interesting and amusing.

The Secretary suggested to the Society that Mr. Whitehouse had given much study to the pyramids and their construction, upon which he was cordially asked to continue his discourse, though the hour was late.

Mr. Whitehouse then explained his theory with regard to the construction of the pyramids, to the great interest of the meeting. To sum up in a few words, he considered them monoliths cut down from conical hills on the spot and revetted with the rock obtained in the process.

It was 11:15 P. M. when the Society adjourned, after a unanimous vote of thanks to Mr. Whitehouse. JOHN W. WESTON, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

OCTOBER 8, 1889.—Meeting called to order by President Warner. The minutes of the preceding regular meeting of September 8 were read and approved.

Mr. C. G. Force made a motion that a committee be appointed by the President for the purpose of conferring with a like committee of the American Society of Civil Engineers, with a view to co-operation in work.

Mr. Warner, President, appointed Messrs. W. H. Searles, John Whitelaw and A. Mordecai to serve on the committee.

C. L. Saunders, G. W. Vaughan and C. S. Howe, applicants for membership of the Society, were favorably reported by the Executive Board.

Mr. J. H. Dow, of Cleveland, read a paper entitled "Notes on a New Compound Steam Turbine," which was discussed by members of the Club.

A vote of thanks was accorded to Mr. Dow for his interesting paper, he not being a member.

Mr. N. S. Possons then read a paper on "Electric Motors as Applied to the Propulsion of Street Cars," which was fully discussed.

[*Adjourned.*] CHAS. O. PALMER, Secretary.

CIVIL ENGINEERS' CLUB OF CLEVELAND.

NOVEMBER 12, 1889.—Meeting called to order, President Warner in the chair.

The Secretary read the minutes of the previous meeting of the Club, which were approved.

The Executive Board and Committee on Membership having recommended Charles Sumner Howe, George Washington Vaughn and Cecil L. Saunders be admitted into active membership of the Club, a ballot was taken which resulted in their unanimous election.

A communication from the Executive Board was read recommending that William B. Cleveland, Royal Gurley, Hiram A. Tucker, and Herman Poole be admitted active members of the Club.

Mr. W. H. Searles, Chairman of the Committee on Engineering, made his report in substance as follows (the written report of the committee was not

at hand, being in the possession of one of the committeemen not present): The committee felt that any overtures having in view the matter of a closer alliance between the Club and the American Society of Civil Engineers should properly come from that society. A closer alliance with other societies was also recommended.

Mr. Mordecai offered the following resolution, which was adopted: "That the Chairman of the Committee appointed at the last meeting of the Club be requested to communicate with the Committee appointed by the American Society of Civil Engineers, and state to them that this Club will receive and carefully consider any communications they may be pleased to make looking toward closer affiliation with that Society.

The paper of the evening entitled "Recent Developments in Steel and Iron Manufacture" was read by Mr. Geo. Bartol.

Mr. Force made a motion that the members meet again on November 26, 1889, for a further discussion of Mr. Bartol's paper: Also for the reading of of papers—one by Mr. Warner entitled "Stellar Photography," and one by Mr. N. B. Wood, entitled "Facts and Speculations regarding the Planet Mars." Carried. It was the intention that these papers should be read at this meeting as supplemental papers, but the time necessarily consumed in the elucidation of Mr. Bartol's points rendered it impracticable without continuing the meeting beyond a seasonable hour.

A motion to adjourn by Mr. Wood was put and carried, Vice-President Thompson in the chair. C. O. PALMER, Secretary.

MONTANA SOCIETY OF CIVIL ENGINEERS.

OCTOBER 12, 1889.—Pursuant to a call issued by the President, the 8th inst., a special meeting was held at 8 P. M., at the office of Mr. E. H. Beckler, Chief Engineer Montana Central Railway, President B. H. Greene in the chair. There were present Messrs. Wheeler, Helmick, Herron, Foss, Cumming, De Lacy, Haven, Sizer and Keerl.

The meeting was called to take action upon a communication of Aug. 7, 1889, from Mr. William P. Shinn, Chairman of the Committee on Revision of the Constitution and By-Laws of the American Society of Civil Engineers, and for the appointment of a Nominating Committee to name officers for the ensuing year.

The communication from Mr. Shinn called attention to certain resolutions adopted by the American Society of Civil Engineers at its annual convention held at Seabright, N. J., on June 24, 1889, and especially to the fifth resolution, which authorized his "committee to confer with any committee appointed for the purpose by the local engineering societies," with a view of determining whether a satisfactory basis can be established for affiliation therewith, and requesting that a committee representing this Society be appointed for the purpose of conferring with his committee on the subject of the resolution.

A communication was read from the committee of the St. Louis Engineers' Club, appointed in conformity with a similar request, inclosing the minutes of the Club's meeting of Sept. 11, 1889, setting forth the action of that Club upon the question of affiliation, being favorable to the movement.

The article by Prof. J. B. Johnson, M. Am. Soc. C. E., upon "An American Society of Civil Engineers" was read from the *Railroad Gazette* of Aug. 23, 1889, and was recognized as a very able and comprehensive review of the question of affiliation. Discussion upon the general subject ensued at some length.

Mr. Sizen moved, that it is the sense of this Society that an affiliation with the American Society of Civil Engineers would be desirable. Carried.

Mr. Haven moved that a committee of five be appointed to consider the subject, and to report at the regular meeting of the 19th inst. Carried. Committee named: Messrs. Haven, Sizer, Foss, Herron and Keerl. Mr. Haven moved that the Secretary be instructed to convey to Mr. Shinn the action of this meeting. Carried.

The Chair named the following to constitute the Nominating Committee to name officers for the ensuing year: Messrs. Wheeler, Wilson and Page.

A letter was read from Mr. Charles G. Griffith, suggesting the advisability of this Society taking steps looking to securing improvements in the manner of conducting public land surveys, and requested a consideration of the subject at the meeting of the 19th inst. The Secretary was instructed to notify Members that the subject would be presented at the next regular meeting.

[*Adjourned.*] J. S. KEERL, Secretary.

OCTOBER 19, 1889.—The regular monthly meeting was held at 8 P. M. at the office of Mr. E. H. Beckler, Chief Engineer Montana Central Railway, President B. H. Greene in the chair. There were present Messrs. Haven, Kelley, Foss, Griffith, Wheeler, Herron, De Lacy, Keerl, and as visitors Messrs McRae and Brown.

The minutes of the meeting of July 20 and of the special meeting of Oct. 12 were approved.

An application for membership was read from Charles F. Pearis; filed and letter ballots ordered.

Col. De Lacy, of the Committee on Memorial to the Constitutional Convention, made a verbal report and submitted the Memorial which had been presented to the Convention. The Memorial asked for the establishment of the office of State Engineer, which the Convention concluded should be left to the action of the Legislature. Report accepted, Memorial filed, and committee discharged.

A report was submitted by Col. De Lacy, Chairman of the Committee on Irrigation in Montana, stating that they had prepared a report with maps, covering the present condition of irrigation in Montana, and had presented the same to the U. S. Senate Committee on Irrigation at their Helena meeting. It consisted of three parts, viz., first, the general report; second, a detailed report of each county, and, third, a recapitulation. The reports were ordered filed and committee discharged.

Colonel DeLacy, Chairman of the Committee on Public Land Surveys, read as a preliminary report a very interesting paper upon the history of public land surveys, in which he suggested several improvements in the service. He referred particularly to the loose manner in which many surveyors of public lands, who worked under contract, were in the habit of executing surveys; how work was done or left undone and money collected by them for such work. He suggested as a remedy that the Government appoint a regular survey bureau in each survey district, consisting in addition to the Surveyor General and staff of a competent public surveyor and topographer, who shall be in the regular employ of the Government under salaries. After a discussion of the subject at some length, Mr. Charles G. Griffith was added to the Committee on Public Land Surveys, and the Committee authorized to draw up a memorial to Congress concerning the matter. The question as to advisability of the Committee securing the co-operation of all sections in which public land surveys were being made was discussed. Mr. Kelley moved that the Committee be authorized to proceed in such manner as in

their judgment seems best, with request that they make a report at the next regular meeting. Carried.

Mr. W. A. Haven, Chairman of Committee on Affiliation with the American Society of Civil Engineers, submitted the following report:

To the President and Members of the Montana Society of Civil Engineers.

GENTLEMEN: Your committee, to whom was referred the communication of August 7, 1889, from Mr. William P. Shinn, Chairman of the Committee on Revision of the Constitution and By-Laws of the American Society of Civil Engineers, relative to the question of an affiliation with that Society, would respectfully make the following report:

We have held two meetings and have discussed the various features that would appear as controlling this movement, and while being fully agreed that an affiliation which would create a closer union of all engineering societies would be accompanied by great advantages to the profession at large, and tend to forward it to that assertive position which its importance to the public would appear to justly demand, we would deem it unwise at this early day in the consideration of this question to advise the adoption by this Society of a basis upon which it would indorse an affiliation to which it might feel itself for the future committed.

Appreciating the scope of this movement, and with the main purpose of considering its possible relation to the Association of Engineering Societies, Mr. Benezette Williams, Chairman of the Board of Managers of the Association, by letter of Oct. 8, 1889, to our member of the Board, has suggested that a meeting of the Board be held in November to discuss this question, and to act upon other business vital to the welfare of the Association.

By letter of October 11, 1889, from Mr. Shinn, Chairman of the Committee of the A. S. C. E., we are advised that further time will be granted for the consideration of this question than at first named.

We would therefore recommend that this Society secure representation at the proposed meeting of the Board of Managers of the Association of Engineering Societies, believing that such Board is in a position to more thoroughly discuss and more competent to suggest a basis for affiliation than the individual societies; and further, that a Committee of three be appointed to confer with the Committee of the A. S. C. E., as requested by letter from Mr. Shinn, of August 7, 1889, and that the Chairman of such Committee be named as the representative at the proposed meeting of the Board of Managers of the Association of Engineering Societies, that proper co-operation between the Society's representatives upon this question may be secured.

Your Committee are of the opinion that one of the most useful ends that would appear as practicable of attainment—should an affiliation be perfected—would be the establishment of a Circulating Engineers' Library, and centrally located, to be readily available to all the societies included in the affiliation; and we would further recommend that the above-named representative and committee be instructed to use every effort that may appear advisable looking to such accomplishment.

W. A. HAVEN,
G. O. FOSS,
JOHN HERRON, Committee.
F. L. SIZER,
J. S. KEERL,

After a discussion of the question Mr. Kelley moved that the report be adopted and committee discharged. Carried.

The chair appointed Messrs. Haven, Herron and Keerl a committee to confer with the committee of the American Society of Civil Engineers upon the question of affiliation.

Mr. Foss stated that Mr. Haven had addressed to the Committee on

Affiliation a willingness to represent the society at the proposed meeting of the Board of Managers of the Association of Engineering Societies, as he expected to be East during November.

On motion of Mr. Herron, Mr. Haven was authorized to represent the Society at the proposed meeting of the Board.

Mr. Keerl moved that a Committee on Membership be appointed and entrusted with the duty of looking to the enlargement of the Society, through endeavors to have embraced by the membership all engineers of good standing who claimed residence in Montana. Carried. Committee named Messrs. Walter S. Kelley, of Helena; Jos. H. Harper and John Gillie, of Butte.

[*Adjourned.*] J. S. KEERL, Secretary.

Editors reprinting articles from this journal are requested to credit both the JOURNAL *and the Society before which such articles were read.*

ASSOCIATION OF ENGINEERING SOCIETIES
ORGANIZED 1881.

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This Association, as a body, is not responsible for the subject matter of any Society, or for statements or opinions of any of its members.

NOTES ON A NEW COMPOUND STEAM TURBINE.

BY J. H. DOW.

[Read before the Civil Engineers' Club of Cleveland, October 8, 1889.]

The new motor which you kindly permit me to show you is a compound steam turbine. It has six compoundings, and consequently uses the steam six times over; but the method of its construction would have permitted any desired number of compoundings. Its weight, as it stands,* is 68 pounds. It has been used to run an elevator, a pump, a dynamo. When running the elevator it developed 4,450 foot pounds of work for each pound of steam pressure. At this rate 70 pounds pressure performs about 10 horse power of work. The consumption of boiler feed water required to run the turbine at 70 pounds pressure is 585 pounds per hour, but the net evaporation is fully 20 per cent. less than this, or 468 pounds per hour, if two calorimeter tests, taken at another time, correctly show the average dryness of the steam. The consumption of steam per actual horse-power per hour would then be $\frac{468}{10} = 47$ pounds.

Very recently this turbine has been coupled to the lighting dynamo at the Chisholm Steel Shovel Works, and with 70 pounds of pressure in the steam chest, it has run the 13 arc lights of the works at their full brilliancy.

The speed of the turbine when running the elevator was 21,000 revolutions per minute; when running the dynamo with a 13-light current the speed was between 16,000 and 17,000. In each case the speed was reduced by gears at an undetermined waste of power.

Without gears, but by direct coupling, the turbine has successfully run a specially constructed rotary pump at a working speed of about 10,000 revolutions per minute, and the power developed was apparently as great as at the higher speed with gears. The speed of highest efficiency is theoretically more than 25,000 revolutions per minute, if the half velocity of the issuing steam determines the best velocity of the wheels; but I suspect that other factors enter into that problem, and that satisfactory work may be done over a large range of speeds.

The spindle and propeller wheels which I hold in my hand constitute

*The motor stood upon a table in front of the audience.

the entire running parts of the pump, which you, Mr. President, and several of the gentlemen present have seen in operation,* I will not say just how much water these wheels throw per minute through a three-inch nozzle, but it is *more* than 20 barrels.

The power of the steam turbine is explained by the principle that a jet of steam blowing into a vacuum will throw its whole energy into momentum. If, therefore, a turbine could be made which would utilize the entire momentum of the steam jet it would be equal in efficiency to a theoretically perfect piston engine. But the extreme lightness of steam compels a greater speed of motor than has ever been successfully used: and the elasticity of steam, as contrasted with the non-elastic nature of water, compels the compounding of the steam turbine, though compounding the water turbine would destroy its efficiency: for the momentum of the steam, though checked by the first series of buckets, recovers itself instantly by expansion, and must be checked again and again by successive series of buckets until the steam has spent its expansive force.

Prof. Webb, of the Stevens Institute of Technology, says that the steam turbine may develop mechanical energy "with a high degree of economy," provided that the difficulties of mechanical construction can be overcome. He says also, "The advantages of a successful turbine are too apparent to need mention, and I hope to hear of progress in this direction."

Whether my new turbine is along this line of progress you may better judge after the following

DESCRIPTION.

Fig. 1 is an end elevation of the motor without the cover and end wheel. The lay out of the stationary chutes, or guide plates, of the turbine is shown in full lines. Dotted lines show the wheel buckets.

Fig. 2 is a longitudinal section of the motor. The arrows show the direction of flow of the steam.

The interior of the shell is divided into three chambers by two partitions *P P* parallel with the covers. The central chamber *A* receives live steam by the steam pipe entering at the top. The chambers *B B* next to the covers are for exhaust steam, which is discharged from both chambers through a single exhaust pipe *E*, which leads from a connecting passage between the chambers. The driving spindle *D* is concentric with the chambers, and is journaled in the hubs of the covers. It carries at the inner end of each exhaust chamber an aluminum bronze wheel *W W* of about 5½ inches diameter, whose inner face has six circular tongues and grooves concentric with the wheel. Into these engage similar tongues and grooves cut upon the outwardly presenting faces of flange disks *F F*, which are secured by screw threads into the partitions. All tongues bottom in their grooves, but they are separated from each other at the sides by annular spaces, the grooves being considerably wider than the tongues. Each tongue upon disks is cut slantingly across at regular spacings by steam passages, analogous to the guide plate vents of water turbines; and similar passages, but inclined oppositely to these, cut across

* There are two propeller wheels, a right and a left, mounted on a single shaft. Each wheel weighs 6¼ ounces. The total weight of wheels, spindle, and coupling to connect them with motor spindle is two pounds three ounces.

SCALE.

0 1 2 3 4 5 6 7 8 INCHES

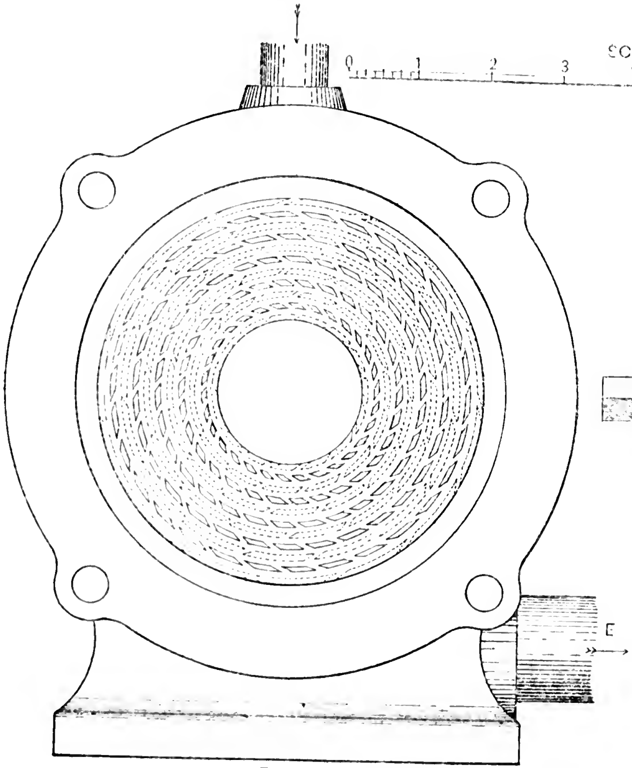

Fig. 1.

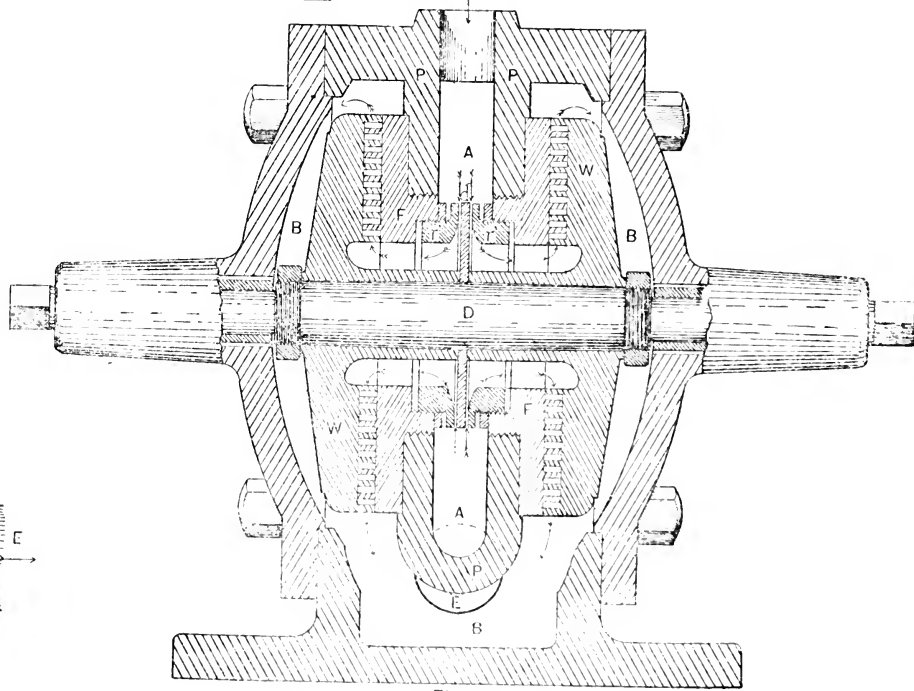

Fig. 2.

the wheel tongues like the bucket vents of water turbines. The wheels W W have long hubs, inward projecting; and the bore through the flange disks F F is large enough to leave annular steam passages around the hubs. The hubs clamp a plain disk d between them on the spindle midway of the steam chamber, and this disk runs with equal clearance between the stationary rings r r. These two clearance spaces are the two steam ports, as shown by the arrows in Fig. 2.

Each port supplies only its own wheel with steam, which flows inward to the wheel hub, then along the annular space surrounding the hub to the inner series of buckets. These deflect its course, check its velocity, and receive impulse by the reaction. The checked steam is then easily reversed in its direction by passage through the first series of stationary chutes, which have, as in every series, a much larger aggregate area of discharge than the adjacent bucket vents. While the steam is passing through the chutes expansion is accelerating the velocity of the flow, to be again checked by reaction upon the second series of buckets. And so, check by reaction, and acceleration by expansion, alternate, until finally the spent steam escapes from the circumference of the wheels into the exhaust.

An extremely slight end play is given to shaft, wheels and central disk, so that any disturbance of steam balance upon the opposing wheels will crowd the central disk toward one or other of the stationary rings r r. This movement partly closes the port leading to the overpressed wheel, at the same time opening wider the other port, and the equilibrium restores itself. In practice an end play to the shaft and wheels of .005 of an inch is sufficient to prevent frictional contact of wheels against their seats.

The annular spaces between buckets and stationary vents insure constant flow of steam and its even distribution around the circumference at each compounding; and whenever the speed of the wheels is below the normal, due to the velocity of the outflowing steam, there will be a circular rush of steam around these annular spaces, which will impinge against the buckets and thereby assist to propel them. Hence the annular spaces enlarge the range of effective speeds.

The advantages claimed for this compound steam turbine are: extreme simplicity, compactness, lightness and cheapness; freedom from friction, and perfect steadiness of pull with consequent smoothness of action; also, extraordinary storage of power in the momentum of the steam wheels (about 10,000 foot pounds), giving unusual steadiness under sudden changes of load.* In comparison with the reciprocating piston engine the steam turbine has the advantage that no part is subject to alternate heating and cooling; hence, steam expansion operates under more favorable conditions, and may give better results. The turbine may use the highest steam pressure with advantage, for its normal speed under high pressure dense steam does not greatly exceed the speed required for the rarer steam of low pressure. The gyroscope principle is extremely developed by the steam turbine, and may yet be utilized with startling effect. But undoubtedly the first call for the perfected steam turbine will be to run the dynamo by direct couplings.

*A 1,000 pound fly wheel of usual proportions, running 150 revolutions per minute would store about 8,000 to 9,000 foot pounds.

Fig. 3 is from a photograph of the motor and reducing gears which drive the dynamo. The motor is the cylinder with bulging covers at the right-hand end of the bed plate. In line with the motor-driving spindle, and coupled with it, is a small pinion, not seen in the cut, which runs between the two wide, triple-toothed gears at the right of the train, and engages into both. The power is then transmitted, half by one gear shaft

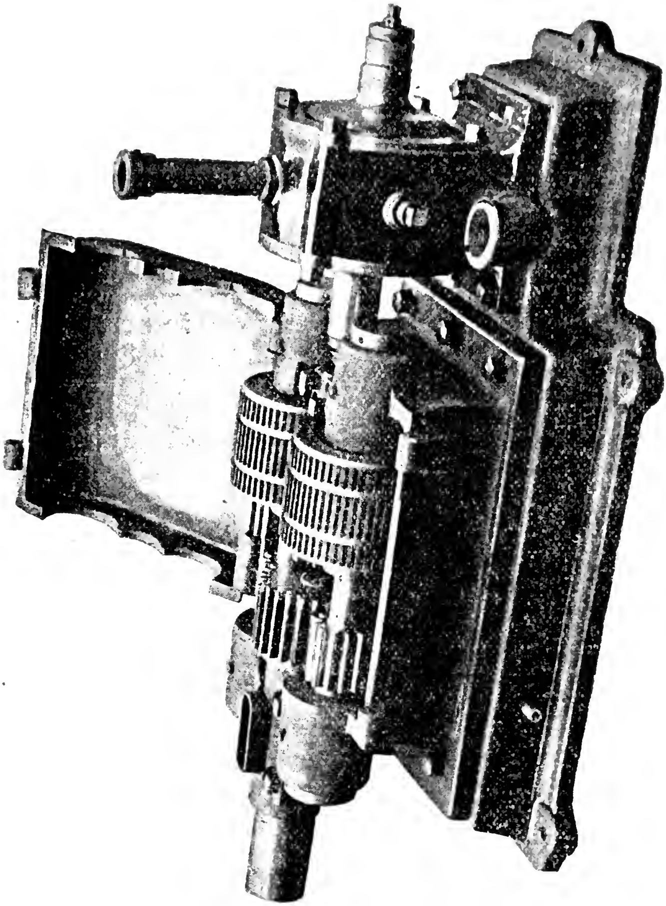

Fig. 3.

and half by the other, to the pinions at the left of the train, both of which drive the gear between them with its shaft. This shaft runs at the speed of the dynamo, whose armature it drives by direct coupling. The total weight of motor and gears, mounted as shown, is about 400 pounds. The floor space occupied is 2 feet 9 inches × 1 foot 6 inches.

At a not distant future day you may receive a report of tests of the efficiency of this turbine more accurate and reliable than any which *I* can give you. Nearly all the tests which I have made have been com-

parative, not absolute; but by their aid I have improved the motor, little by little, to ten-fold its first efficiency. Without doubt, it may, and will, be further improved.

In conclusion, accept my thanks for the courtesies of this evening.

The discussion on Mr. Dow's paper was briefly as follows:

Mr. J. H. Dow: This machine has developed ten horse power.

Mr. C. G. Force: I was present at a measurement of the number of revolutions the wheel of the machine made for a minute—23,000 being the number noted. Afterward it was run still faster.

On examining one of the wheels my first impression was that it was "Barker's Cylindrical Mill," multipled. I would like to ask if I am correct.

Mr. Dow: The Barker mill has commonly used water as the propelling fluid. The operation of steam is radically different from water, because steam is elastic while water is non-elastic. If I put water pressure in that turbine I fail to get any power at all; for all the force of water will be expended upon the first series of buckets, and succeeding series are worse than useless; they are hindrances. On the other hand, the expansive energy of steam instantly renews momentum after each check at the successive series of buckets.

In the respect of reactions this motor is like the Barker mill; but it is unlike the Barker mill, and like the water turbine, in that the steam first flows between stationary guide plates, and operates upon the buckets by impact in the direction of their motion, before reacting from them in the opposite direction. This double action of the fluid upon the buckets gives, theoretically, to the turbine double the efficiency of the Barker wheel.

Mr. Barber: The old "Hero" engine was made on the principle of the Barker mill. It was illustrated in our books on the early steam engine. The steam flows out of pipes and reacts against the wheel. I suppose the theory of it is that the steam is admitted into the pipe and the pressure is equal on all sides of it, and the operation is reactionary.

Mr. Dow: It may be reactionary in a certain degree, but the impact is directly on a little feather, which is contrary to the operation of the Barker mill.

Mr. Force: That feather you speak of is stationary as I understand.

Mr. Dow: One part of the steam turbine is stationary; the other revolves.

Mr. Barber: As I understand the turbine wheel, it is a combination of two principles: the reactionary principle of the Barker mill and also the impact system of the overshot wheels or any of the water wheels—simply a combination of these two.

Mr. W. H. Searles: I have had the pleasure of seeing this machine work, and the impression I get here to-night is that one must see it work in order to appreciate it. No written description or diagram will convey to the mind the wonderful performance of this little machine. I was invited to witness its operations and went with some misgivings. Like others, I had little faith in the motor. I saw the parts separate and afterward in motion, and caught the idea at once, and must admire its simplicity and great efficiency. I certainly have great hopes of this little machine filling a place in the mechanical world that has hitherto remained unoccupied.

Mr. Wood: What is the effect of its running so extremely rapid? Is it noisy? Is it difficult to hold in position?

Mr. Searles: The machine runs almost noiselessly, and, as was described in the paper, it so regulates itself that the motion is steadied.

ASSOCIATION OF ENGINEERING SOCIETIES.

PROCEEDINGS.

Minutes of the Meeting of the Board of Managers of the Association of Engineering Societies, held in Chicago, December 3 and 4, 1889.

CHICAGO, December 3, 1889.

The meeting was called to order by the chairman, Benezette Williams, of the Western Society, and J. B. Johnson, of the Engineers' Club of St. Louis, was elected secretary *pro tem.*

There were present: Benezette Williams and L. P. Morehouse, of the Western Society; S. E. Tinkham, of the Boston Society; W. H. Searles, of the Cleveland Club; Wm. B. Knight, of the Kansas City Club, and Wm. H. Bryan and J. B. Johnson, of the St. Louis Club, these being a quorum for the transaction of business.

The Chairman stated the object of the meeting to be the election of officers of the Board, making a new, or renewing the old, arrangement for the publication of the JOURNAL, and to consider the question of a closer affiliation of the engineering societies of the country.

After a general discussion of the powers of this Board and the desirability of a national organization of engineering societies, it was moved by Mr. Knight that a Committee of three be appointed by the Chair to formulate amendments to the present Articles of Association, and report at an adjourned meeting.

The motion prevailed, and Messrs. Tinkham, Searles and Bryan were appointed as such committee.

It was moved by Mr. Johnson that the Chairman appoint a Committee of this Board to prepare an address to the various engineering societies of this country on the subject of a national organization and to submit a progress report to an adjourned meeting of this Board for approval.

Messrs. Johnson, Knight and Searles were appointed on such committee.

The Board then adjourned to meet on the following day.

DECEMBER 4, 1889.—The Board was called to order by the Chairman. Present, Messrs. Williams, Morehouse and Gottlieb, of the Western Society; Tinkham, of Boston; Searles, of Cleveland; Knight, of Kansas City, and Johnson, of St. Louis.

Mr. Searles reported the following amendments to the Articles of Association:

Amendment I.—Upon application to the Board of Managers by any Society member of this Association, the Board shall have power to lay before the several societies any question of scientific, technical or professional interest, with the request that each Society investigate the subject named. and report upon the same to the Board by a certain date. Upon the receipt of the several reports the Board shall formulate a general report embodying the facts and in accordance with the general sense and tenor of the local reports, and this report shall be published in the JOURNAL as the sense of the Association.

Amendment II.—The Board of Management may make recommendations on any subject affecting the policy of the Association or the mutual rela-

sions of the participating societies, and submit the same in the form of resolutions to be acted upon by the several societies. If these resolutions be adopted by two-thirds of the societies, they shall become the law of the Association, and binding upon all participating societies.

The report was accepted and the committee discharged.

The amendments were then adopted by the Board, and the Chairman was instructed to submit them to the several societies in the Association for their ratification.

Mr. John W. Weston submitted the following proposition for publishing the JOURNAL:

CHICAGO, Ill., Dec. 4, 1889.

To the Board of Managers of the Association of Engineering Societies:

GENTLEMEN:—I hereby propose to publish the JOURNAL of the Association of Engineering Societies, for one year, in similar form and typography to that heretofore obtained, subject to all the conditions now incorporated in the contract with the *Railroad Gazette*, hereto attached, for the sum of $2.75 for each subscriber in the Association, and for $3.00 for outsiders. I further propose to endeavor to increase the income of the JOURNAL from advertising and other sources, to perform all the duties of the Secretary of the Board, and at the end of the year to open to the inspection of the Board all the expenses and accounts of the year's transactions.

Signed, JOHN W. WESTON.

After a general discussion, the proposition was accepted, to take effect with the April number of the JOURNAL.

Mr. Johnson made a progress report for his committee, outlining a scheme for the formation of a federation of all engineering societies in America, and the skeleton of an address to such societies on this subject.

The Committee was continued and instructed to perfect the address and submit it to all the members of the Board for their approval.

The Board then proceeded to the election of officers.

Mr. Benezette Williams was unanimously elected Chairman and Mr. John W. Weston Secretary, his duties to begin with the transfer of the duties of publisher to him by the *Railroad Gazette*.

The following resolution was unanimously adopted:

Resolved, that the thanks of this Board be extended to Mr. H. G. Prout for his long and efficient services as Secretary, and that we regret the termination of his official relations with the Board.

The Board then adjourned to meet at the call of the Chairman.

J. B. JOHNSON, Secretary *pro tem.*

ENGINEERS' CLUB OF ST. LOUIS.

314TH MEETING.—November 20, 1889: The Club met in the large hall of the Elks Club, Laclede Building, at 8:15 P. M., President Meier in the chair; thirty-nine Members and five visitors present. The minutes of the 313th meeting were read and approved. The Executive Committee reported the doings of its 77th and 78th meetings. The Secretary announced an application for membership from R. S. Conlon, civil engineer in the office of Johnson & Flad. This was referred to the Executive Committee.

The amendments to the by-laws, which had been announced by mail one week previous, were then taken up. The Secretary read the sections as they were now and as they would stand as amended. It was moved and seconded that these amendments be adopted. It was on vote ordered that the amendment be amended so that the increase of initiation fee take effect after January 1, 1890. The amended section of the by-laws would then read as follows.

SEC. 2. After January 1, 1890, the initiation fee shall be ten dollars ($10). The annual dues shall be fixed at the beginning of the year by the Executive Committee, but such dues shall not exceed for resident members ten dollars ($10), and for non-resident members, six dollars ($6). Members elected after the last meeting in June shall have the option of not taking the *Journal* for that year, and having three dollars ($3) deducted from their annual dues of that year.

The amendment as amended was then voted upon and carried; moved and seconded that this vote be reconsidered; laid on the table.

The club then proceeded to ballot for a committee on nominations of officers, which resulted in the election of Messrs. Robert Moore, R. E. McMath and M. L. Holman. It was on motion ordered that the chair appoint a standing committee of five to consider all questions regarding library and reading room. It was on vote ordered that the chair also appoint a standing committee of three on future permanent location. The chairman announced that he would appoint these committees during the week. The secretary announced that arrangements had been perfected with the Elks Club, by which a meeting place could be had as desired on payment of $5 per evening.

Mr. Robert Moore then addressed the club on the subject of "Railway Culverts." This question was usually given too little attention. The speaker described the various forms of culverts used, with the advantages and disadvantages of each; also stated the methods of determining the size and best mode of construction. He stated that sewer pipe, while admirably adapted for small culverts, should not be used over 15 inches in diameter. For larger sizes cast-iron pipe answered well. Cast-iron pipe which had been condemned for heavy pressures, was being largely used for this purpose. Mr. Moore also presented a diagram, based on Kutter's formula, using a value of 17 for n, bearing in mind that one inch of rainfall per hour is equivalent to one cubic foot per acre per second. In the discussion, Mr. Ferguson described a number of practical points of difficulty he had met with. The discussion was also participated in by Messrs. J. A. and W. L. Seddon, M. L. Holman and A. W. Hubbard. Mr. Holman stated that iron pipe for this purpose was being made as large as six feet in diameter and ten feet long, being lighter and of a poorer quality than the pipe used for water service. Messrs. Johnson & Flad then extended to the club an invitation to meet after the close of the meeting, in their office adjoining the club rooms on the third floor of the Laclede Building.

[*Adjourned.*] WILLIAM H. BRYAN, Secretary.

315TH MEETING—December 4th, 1889: The annual meeting was held in Elks Club Room, at 8.15 P. M., Vice-President Nipher in the chair; thirty-one members and three visitors present. The minutes of the 314th meeting were read and approved The Executive Committee reported the doings of its 79th meeting, at which the privileges of Edward Hall, who had been elected to membership, but had not qualified, were declared forfeited, and the application of R. S. Conlon for membership had been approved. Mr. Conlon was then balloted for and elected. An application for membership was announced from B. H. Colby, in charge of surveys, sewer department, city of St. Louis, indorsed by J. B. Johnson and R. E. McMath. This was referred to the Executive Committee.

Mr. Seddon, chairman of the Committee on Library, announced that arrangements had been made to keep the club room open from 7.30 to 11 on Saturday evenings.

Mr. Robert Moore submitted the following report from the Standing Committee on Collection of Local Engineering Data:

PROGRESS REPORT OF COMMITTEE ON LOCAL DATA.

At the meeting of the Engineers' Club, May 1, 1887, the following was adopted:

WHEREAS, The collection and exchange of data are a proper mission of the Club,

Resolved, That a standing committee be appointed to compile a book of local data to be presented for publication at the next annual meeting—the book to contain such information in regard to the materials of engineering in use in St. Louis and vicinity as can be collected, and other memoranda of a local nature useful to engineers, the committee to call on such members as it may select for assistance in the compilation.

Notes on the following subjects have been contributed by members: Excavation, pile driving, and brick concrete and stone masonry. Labor and cost of, by Thomas McMath and C. V. Mumn.

Specific gravity and absorption of stone and brick, by S. F. Burnet.

Analysis of stones, clays and cements, by T. J. Caldwell.

Surface drainage and city sewer practice, by R. E. McMath.

Average and extreme rainfall, by F. E. Nipher.

Sediment, hardness and chlorines of river water. Average and extreme stages of river at city. Periods of suspension of navigation by ice, by J. A. Seddon.

Fuel required to heat buildings, by E. D. Meier.

Cost of earth borings, by J. A. Seddon.

Miscellaneous notes, by M. L. Holman.

Prof. Potter has in preparation a large collection of data on the fuels of St. Louis and vicinity.

S. B. RUSSELL, Chairman.

It was ordered that the committee be continued and requested to present a final report as soon as convenient.

The Special Committee on Nominations of Officers for the coming year reported as follows: For President, F. E. Nipher; Vice-President, Geo. Burnet; Secretary, W. H. Bryan; Treasurer, Chas. W. Melcher; for Directors, E. D. Meier and S. B. Russell; Librarian and Manager, J. B. Johnson; Manager, J. A. Seddon.

The report was accepted and the following additional nominations were made: For Vice-President, S. B. Russell; for Director, F. H. Pond.

Prof. Nipher announced that Prof. T. C. Mendenhall, Superintendent of the Coast Survey, would visit St. Louis soon. Ordered that the president extend an invitation to Prof. Mendenhall to address the club on any subject that he might choose; ordered also that the club extend to Prof. Mendenhall a banquet while in St. Louis; ordered that a committee of three be appointed to arrange for this banquet. The president appointed as such committee, E. A. Engler, Ed. Flad, W. W. Penney.

The annual reports were then presented from the Executive Committee—Secretary, Librarian and Treasurer; the latter being referred to the Executive Committee to be audited.

ANNUAL REPORT OF EXECUTIVE COMMITTEE, DECEMBER 4, 1889.

To the Members of the Engineers' Club of St. Louis:

GENTLEMEN: Your Executive Committee has held 18 meetings. Twenty-five applications for membership have been referred to this committee for consideration; 24 have been approved.

Two members have been dropped from the rolls for delinquency, and two persons elected, but not qualified, have had their rights cancelled.

Fourteen papers have been approved for publication in the JOURNAL.

Forty-seven bills have been approved as follows:

Railroad Gazette	$525.25
Club-room	216.25
Secretary	100.00
Printing	105.85
Rent and janitor	23.00
Postage, etc.	20.95
Menu card	16.00
Library	9.65
	$1,016.95

At the direction of the club, this committee has leased and furnished Room 46, Laclede Building, for permanent headquarters for the club. The cost has been $216.35. Additional furnishings required will bring this amount up to about $250.

Your committee has during the year considered and reported upon the questions of "Transfer of Membership" and "Affiliation with the American Society."

ANNUAL REPORT OF THE SECRETARY, DEC. 4, 1889.

To the Members of the Engineers' Club of St. Louis:

GENTLEMEN: The Secretary has to report that the year just closed has been one of great prosperity. Not only has there been a large increase in the membership and average attendance at meetings, but the number and character of the papers and discussions presented have been better than ever before, and the interest manifested in the welfare of the club is of the most gratifying character.

Eighteen meetings have been held; ten at the Washington University; four in the rooms of the Elks' Club; three in the Polytechnic Building, and one at the Mercantile Library. President Meier occupied the chair at twelve meetings; Vice-President Nipher at three; M. L. Holman at two, and Robert Moore at one.

The average attendance at each meeting has been 30, a gain of two over last year.

The total number of visitors for the year has been 62.

Twenty-eight new members have been elected; our total membership now being 164, divided as follows:

One hundred and fourteen resident members, 49 non-resident, and one honorary.

There have been eight resignations during the year.

Two names have been dropped from the rolls for delinquency. Two persons who were elected, but did not qualify, have also been dropped.

There has been two deaths—Col. H. C. Moore and J. H. Morley.

Papers and discussions have been presented at all the meetings except one, at which the question of "Affiliation with the American Society of Civil Engineers" was considered.

The total number of papers and discussions presented reached 26. At one meeting four were presented, at six meetings two, and at 10 meetings one. Those contributing were:

Prof. J. B. Johnson, 4; Professor Nipher, 2; Col. E. D. Meier, 2, and the following one each: J. H. Kinealy, I. A. Smith, N. W. Eayrs, Carl Gayler, Professor Phillips, W. B. Knight, W. Allderice, B. F. Crow, W. H. Bryan, Professor Brown, A. J. Frith, H. B. Gale, J. A. Seddon, P. M. Bruner, C. H. Sharman, H. A. Wheeler, W. Bartlett and Robert Moore.

The most important action taken during the year has been the securing of permanent and centrally located headquarters for the Club, to be used as a meeting place and library and reading room. The Club's room has already proven its usefulness and popularity.

Among other important subjects considered by the Club during the year were: "Improvements in Highway Bridges," "Transfer of Membership," "Closer Union of Engineering Societies," "Collection of Local Data," and "Affiliation with the American Society."

The records of the Club show the existence of the following:

A special committee of three on "Fire Streams," Mr. Robert Moore, Chairman.

Two special committees on "National Public Works," consisting of five members each, of both of which Prof. J. B. Johnson is Chairman.

A special committee of two on "Monument to Captain Eads," Col. E. D. Meier, Chairman.

A standing committee of five on "Smoke Prevention," Prof. W. B. Potter, Chairman.

A standing committee of five on "Collection of Local Engineering Data," S. B. Russell, Chairman.

A standing committee of five on "Library and Reading Room," J. A. Seddon, Chairman.

A standing committee of three on "Future Permanent Quarters," M. L. Holman, Chairman.

As it appears that some of these committees have outlived their usefulness, it is suggested that some action be taken regarding them. Reports are promised at early dates by Profs. Johnson and Potter for the committees on National Public Works and Smoke Prevention.

W. H. Bryan, Secretary.

ANNUAL REPORT OF LIBRARIAN, DECEMBER 4TH, 1889.

To the Members of the Engineers' Club of St. Louis :

Gentlemen : Your Librarian has to report great prosperity during the past year. The removal of the library to the Club's rooms has made it much more accessible, and has resulted in greatly increased use of it. The thanks of the Club are especially due to the managers of the Index Department of the Engineers' Club, who have transferred to the Club's library all the documents received by them for their services. Many valuable documents and books have also been received from other sources. I have to suggest to the Club several plans by which the value of our library may be enhanced :

1. A systematic application through the proper channels for all reports and other documents of engineering value.

2. The securing of such catalogues of manufacturers and others as are desirable for ready reference.

3. The solicitation and proper care of valuable engineering books which members may be willing to loan to the club.

4. The purchase of a limited number of engineering volumes of value, which it may be impossible to secure in any other way.

I am glad to be able to say that the Library Committee is already working in the directions indicated.

I desire to remind the Club again that the library is now in condition to receive and care for all books, pamphlets and pictures of engineering interest which the members may donate.

W. H. Bryan, Librarian.

REPORT OF THE TREASURER FOR THE YEAR ENDING DEC. 4, 1889.

Receipts.		
To balance from last report	$593 79	
" " from uncollected 1888 dues	142 00	
" dues receipts issued for 1889	713 00	
" " account new members	236 00	
" credit from *R. R. Gazette*	4 00	
		$1,688 79
Disbursements.		
By vouchers paid	$1,024 50	
" dues receipts on hand	111 00	
" " cancelled	75 00	
		1,210 50
To balance		$478 29
Provident bank asset	$52 54	
Cash	425 75	
		478 29

CHAS. W. MELCHER, Treasurer.

Mr. Bryan, Member of the Board of Managers of the Association, made an informal report of the matters under discussion at the recent meeting of the Board in Chicago.

The following resignations were announced: W. L. Breckenridge, H. L. Burnett, T. J. Whitman and H. S. Pritchett.

On motion of Mr. Robert Moore, the Committee on Fire Streams was discharged.

On motion of Mr. Seddon it was ordered that the Committee on Permanent Quarters be increased from three to five. Col. E. D. Meier and Geo. Burnet were appointed the additional members of this committee.

Mr. N. W. Perkins, Jr., then addressed the club on the subject of "Adding Machines." His paper treated particularly of the invention of W. S. Burroughs, of St. Louis, one of which was shown. A full description of the construction and operation was given. Separate parts of the machine were also shown, and its powers were demonstrated by a practical test. The subject was discussed by Messrs. Robert Moore, W. W. Penney, Ed. Flad, Geo. Burnet, J. A. Seddon and M. L. Holman. The machine was specially intended for use in banks, clearing houses, etc. It appeared, however, to be of limited use to engineers, whose work requires but little computation of this kind. Mr. Holman stated, as his experience, that no calculating machine had yet been found to be of great advantage to engineers, from the fact that the problems contained were of so varied a nature, and the number of times which any given process had to be repeated, in identically the same manner, did not justify the use of mechanical devices.

[*Adjourned.*] WM. H. BRYAN, Secretary.

WESTERN SOCIETY OF ENGINEERS.

NOVEMBER 6, 1889:—The 263d meeting of the Society was held at its own rooms Wednesday evening, November 6.

In the absence of the President, the Hon. DeWitt C. Cregier, Mayor of Chicago, Past President of the Society, was called to the chair.

The Secretary made a report on the last meeting of the Board of Directors, at which the following gentlemen were elected: John E. Frohlund, Fremont Hill, George W. Waite.

The following names were also presented for membership: Messrs. O. E. Winger, Wm. H. Wissing, Wm. E. Williams, Geo. E. Dixon, Robert H. Yeats, James L. Armstrong, John L. Van Ornum, Frank E. Herdman, Fred Davis, T. B. Blackstone.

The Society's membership having reached a total of over 250 names, and.

therefore, entitled to another representative on the Board of Managers of the Journal of the Associated Engineering Societies, Mr. A. Gottlieb was elected for the position.

The Chairman then called upon Mr. Liljencrantz for his paper on "Compound Lumber." Mr. Liljencrantz stated that, while the paper had a more direct interest for architects, it was also a matter of importance to any one, either directly or indirectly, interested in building matters.

The material under discussion was the product of the Compound Lumber Company, whose works are established on the Calumet River at Burnham, Ill. It is intended as a substitute for solid hardwood and veneering, now that the finer kinds of hardwood are becoming scarcer and more expensive. Its manufacture is patented, and the product is said to partake of the good qualities of hardwood and veneering, combined with other qualities not possessed by them, with apparently few or none of their defects. It is especially intended for interior finish, such as doors, wainscoting, ceiling, etc. It consists of a core of some soft wood, usually pine, which is faced with certain varieties of hard wood as may be desired or required, the facing being tenoned and grooved upon the core. The core is sometimes covered on all four sides, or on one, two or three sides, as the case may be.

The core and facing are further secured by being glued and forced together by rollers under heavy pressure. Every care is taken in the arrangements of core and facing to provide against warping, and the lumber used is thoroughly seasoned. Compound lumber is lighter to handle than solid hardwood and the core holds the nails better, and the price is below that for solid hardwood.

In the process of manufacture the lumber is brought in the log to the works, trimmed and then run through the veneer saws. After leaving the saw this thin lumber is put in layers to dry, and after a sufficient time is put into the kilns. A week in the kilns prepares it for the factory—the pine going through the same usage as the hardwood.

In the factory this lumber is cut into proper lengths and widths and then run through tenoning and grooving machines, after which the pine base is passed through a glue machine, in which an even coat of glue is spread over the grooved surface. The hardwood top is then placed on the base and run through large roller presses under a pressure of 5,000 pounds. The lumber is now ready for further manufacture.

Mr. Gottlieb opened the discussion, which was taken up by many, and Mr. W. E. Kirkpatrick, Secretary of the Company, was at the Society's service to reply to questions put to him.

A large variety of samples was arranged for the inspection of the members present.

The Chairman next called for the continuation of the discussion on the "Chicago Drainage Problem." In this connection a paper was presented by Mr. H. A. Stoltenberg giving his views why the drainage question cannot be solved by means of the Desplaines River plan, and stating that the best solution of this problem would be to build a system of intercepting sewers along both banks of the river and its branches, as suggested by the former City Engineer, Mr. E. S. Chesborough, in his annual report for the year 1870. The following is a short abstract:

"The Desplaines River plan is based upon the assertion that a dilution of the Chicago sewage equal to 600,000 cubic feet of water per minute for a population of 2,500,000 persons is necessary. Even after expensive widening of the South Branch, not over 300,000 cubic feet per minute could flow through this river branch. All heretofore proposed open canals for this purpose, viz.: Along Thirty-ninth street, along Eighty-seventh street, along

Ninety-fifth street. and through Lake Calumet, would be so expensive and hinder the development of the city toward the south, as to be of no benefit to Chicago, that all of them have practically been dropped. To bring the 300,000 feet per minute through conduits along Thirty-ninth street would cost at least $7,500,000."

The proposed Bowmanville cut-off is useless and impracticable, because the lengthening of the present tunnels four miles into the lake—sufficient to come out of the reach of the sewage altogether—would cost only $750,000, while the Bowmanville cut-off would cost about $2,500,000. After the completion of the Desplaines River plan only the main river and those parts of the river south of it would be improved.

According to the Drainage and Water Supply Commission, the 600,000 cubic feet per minute would be sufficient for a population of 2,500,000, which, according to their own report, would be reached between 1905 and 1915. Their estimate for 1889 has already been exceeded by about 100,000, and the increase during the last year did amount to 110,000. For these reasons it is unlikely that the 2,500,000 will be reached before 1905. But even under the supposition that this 2,500,000 would not be reached before 1910 and the Desplaines River plan would not be finished till 1898, even then this plan would only be sufficient for twelve years.

It is practically impossible to create a strong natural flow in the North Branch and the lumber yards slips by means of the Desplaines river plan, and therefore a clean river cannot, even for a short time, be attained by this plan.

The shipping between the lakes and the Gulf of Mexico would be very little benefited by the flushing channel Chicago-Joliet with a depth of fourteen feet. By means of the 600,000 feet the depth of the Desplaines River would only be brought to seven feet and of the Mississippi river to the mouth of the Ohio river to nine feet. Therefore this channel would have only the value of a seven-foot deep one between the lakes and the gulf. The value of a fourteen-foot deep channel would only be attained if the United States would furnish this depth from Joliet to the Ohio river, but whether this will be done or not is for the present altogether uncertain.

To get a clean river in all its branches is only possible by keeping the sewage out, *i. e.*, to run intercepting sewers along both banks of the river and its branches.

The former City Engineer, E. S. Chesbrough, who has rendered the city incalculable services, says in his annual report for the year 1870: "In view of the present knowledge and experience it does not seem advisable to commence the construction of a system of intercepting sewers just yet, though the probability of having to do so ultimately seems rather to increase from year to year."

By means of these intercepting sewers the sewage should be conducted to Bridgeport and there pumped into the Illinois and Michigan canal. Thus the sewage would come in a fresh condition into the canal, while it is now lying for weeks in some part of the river, and then, in a perfectly decomposed condition, flushed down the Desplaines River valley. A remarkable improvement of the canal would, therefore, take place after the completion of such a system of intercepting sewers.

At some time, however, a scientific treatment of the sewage will become imperative, either by electricity, filtration or any other way.

According to extensive and successful trials of Mr. William Webster, the inventor of this method, at Crossness, near London, the electrical treatment of sewage for a million inhabitants would amount for Chicago to only $161,000 a year, including the rentals for buildings and machinery.

As every scientific treatment of the sewage will require intercepting sewers in advance, the latter should be built under all circumstances.

Such a complete system of intercepting sewers with pumping works for raising the sewage, together with:

a. A plan to force lake water into the eastern end of the stockyards slips.

b. A similar plan to force water into the northern end of the lumber-yards slips.

c. The enlargement of the present Bridgeport pumping works to 100,000 cubic feet per minute.

d. The deepening and widening of the Illinois and Michigan canal:

Would cost in all about $5,500,000. This plan could be built in about two years.

Mr. R. B. Mason presented a written discussion, the leading features of which are about as follows: "The cut-off near Evanston is unnecessary; it would be very costly, require a large sum for maintenance, carry much material into the lake, and do more or less damage to adjoining property. The Desplaines River is the proper channel for the flood waters of that river. The safest plan for drainage would be for the city to avoid the river, as the present canal now does, and prevent any water from the Desplaines from coming to Chicago, or to have gates in the Ogden ditch for regulation. Another plan would be to use the Ogden ditch and make use of deep channels in the Desplaines River from the Summit westward.

The objection to this plan would be that it would not give a direct line to the channel, and that the excavated material, unless deposited on the high ground, would contract the present waterway and aggravate conditions at flood time. Of the 600,000 cubic feet per minute, 200,000 should pass through the Calumet River and Sag near Blue Island and 300,000 through the Chicago River. This would not cost as much as a 600,000-foot channel from Chicago, and would afford drainage to growing localities. It would avoid the expense of channels through valuable property, as well as the Evanston cut-off.

The 600,000 feet per minute in time of freshets would add to the damages in the Illinois Valley, which could be provided against by guard locks near Chicago and in the Sag. The above plan provides for navigable channels in both cases, and would provide more drainage than contemplated in the act, besides saving enormous land damages.

It is worthy of consideration whether the drainage channel should not be constructed to leave both present canal and river in existence, but it might be found well to use present canal as far as rock cut, but it is absolutely necessary to carry out the work with the least possible delay. The 300,000-foot channel would probably be sufficient for several years, and the Sag channel might be postponed, but the latter would ultimately be required. Mr. Mason believed the great advantages would justify the enormous expense involved, and that the ship canal would finally benefit all the country.

Mr. L. E. Cooley, who had provided the maps prepared for the judges, for assistance in the discussion, briefly reviewed the whole project and the legal points involved, opposing in large measure the views of the discussions just presented, giving figures and analyses in support of his position.

Many members, including the Chairman, joined in the discussion. Mr. Stoltenberg's paper was conceded to be out of date, as the great project now under way was the result of years of study and research.

On the close of the discussion the Chairman called the attention of the society to the stock books of the World's Fair Committee, and after explaining the condition of the question and the prospects, urged the members to lend a hand.

[*Adjourned.*] JOHN W. WESTON, Secretary.

ENGINEERS' CLUB OF KANSAS CITY.

NOVEMBER 4, 1889.—A regular meeting was held in the club room at 8 P. M., Vice-President Breithaupt in the Chair, Kenneth Allen, Secretary. There were present eight members and seven visitors.

Minutes of the last regular meeting and meetings of the Executive Committee were read and approved.

The resignation of Mr. F. Allen, as Librarian, on account of change of residence, was presented, and on motion of Mr. F. W. Tuttle it was voted that the Chair appoint a Librarian to act until the end of the year.

The Secretary announced the receipt of 13 pamphlets on Harbor Studies, Permeability of Cements, Rapid Transit, etc., from Prof. L. M. Haupt, and illustrations of the Poetsch-Sooysmith Method of Shaft-Sinking from that company.

On canvass of ballots John R. Braidwood and Robt. M. Sheridan were declared elected Members, and Thos. H. Ashburner as Associate.

The paper on "Building Stones," read Oct. 7, was discussed by Messrs. G. W. Pearsons and Thos. Knight.

A short article from Mr. F. E. Sickels, on "Sewer Ventilation," and one on "Sewage Disposal," by K. Allen, were read by the Secretary and discussed by Messrs. G. W. Pearsons and T. Knight.

A paper from Prof. L. M. Haupt on "A Plan for Outer Harbor off Padre Island, Texas," was read by the Secretary; also a letter from Mr. A. Bonzano indorsing the project; and a paper by Mr. John Willett, on the commercial aspect of such an harbor, was read by the author, illustrated by designs and coast survey charts. The plan contemplates building an iron pier out into the Gulf, 4,500 feet from shore. Then constructing a wharfage sufficient for thirty of the larger ocean vessels and two hundred sail of coasters. He considered this plan far more practicable and wise than to attempt to maintain a channel through the bar that guards entrance to the entire Texas coast. The plan could be carried out in twenty months, and the case of Ceare, Brazil, was cited, where a similar outer harbor, 7,000 feet from the shore, is an absolute realization of all expectations.

After discussion by Messrs. G. W. Pearsons, Thos. Knight and H. H. Filley, Thos. F. Callahan was proposed as Associate by F. C. Gunn and Edw. Butts, and W. J. Lightfoot as Member by Kenneth Allen and W. H. Breithaupt.

[*Adjourned*]. KENNETH ALLEN, Secretary.

INDEX DEPARTMENT.

ANNUAL SUMMARY.

It is proposed to furnish, in this department, as complete an Index as may be of current engineering literature of a fragmentary character. A short note will be appended to each title, intended to give sufficient information to enable the reader to decide whether or not it is worth his while to obtain or consult the paper itself. The Index will be mostly limited to society and magazine articles, and special engineering reports of general interest and value. It is printed in the monthly issues of the JOURNAL, *on but one side of the paper, so that the titles may be cut out and pasted on cards or in a book, and is here collected with additional titles and many cross references.*

LIST OF PERIODICALS INDEXED.

American Architect (Am. Arch.), weekly, Ticknor & Co., 211 Tremont street, Boston, Mass.; single copy, 15 cents.

American Engineer (Am. Engr.), weekly, Gaff Building, Chicago, Ill.; per year, $2; single copy, 5 cents.

American Machinist (Am. Mach.), weekly, 96 Fulton street, New York; per year, $2.50; single copy, 5 cents.

American Manufacturer and Iron World (Am. Mfr.), weekly, Pittsburgh, Pa.; per year, $4; single copy, 10 cents.

Electrical Review (Elec. Rev.), weekly, 22 Paternoster Row, London, E. C.; per year, 21s. 8d.; single copy, 4d.

Engineering and Building Record (Eng. & Build. Rec.), weekly, 277 Pearl street, New York; per year, $4; single copy, 10 cents.

Engineering News (Eng. News), weekly, Tribune Building, New York; per year, $5; single copy, 12 cents.

Engineering and Mining Journal (E. & M. Jour.), weekly, 27 Park Place, New York; per year, $4; single copy, 10 cents.

Engineering (Lond. Eng.), weekly, London, England; per year, $10; single copy, 25 cents.

Indian Engineering (Ind. Eng.), weekly, Calcutta, India; 18s. per year; single copy, 8 Annas.

Journal of the Franklin Institute (Jour. Fran. Inst.), monthly, Franklin Institute, Philadelphia, Pa.; per year, $5; single copy, 50 cents.

Journal of the Association of Engineering Societies (Jour. Assn. Eng. Soc.), monthly, 73 Broadway, New York; per year, $3; single copy, 30 cents.

Journal of the Society of Arts (Jour. Soc. Arts), weekly, London, England; single copy, 6d.

Mechanics (Mechanics), monthly, 907 Arch Street, Philadelphia, Pa.; per year, $1; single copy, 10 cents.

Power (Power), monthly, 113 Liberty Street, New York; per year, $1; single copy, 10 cents.

Proceedings American Institute of Mining Engineers (Proc. A. I. M. E.), 13 Burling Slip, New York; per year, $5.

Proceedings of the United States Naval Institute (Proc. U. S. N. I.), quarterly, United States Naval Institute, Annapolis, Md.; per year, $3.50; single copy, $1.

Progressive Age (Prog. Age), semi-monthly, 30 Park Place, New York; per year, $3; single copy, 15 cents.

Railroad and Engineering Journal (R. R. & Eng. Jour.), monthly, 45 Broadway, New York; per year, $3; single copy, 25 cents.

Railroad Gazette (R. R. Gaz.), weekly, 73 Broadway, New York; per year, $4.20; single copy, 10 cents.

Railway Review (Ry. Rev.), weekly, The Rookery, Chicago, Ill.; per year, $4.

Scientific American Supplement (Sci. Am. Sup.), weekly, 361 Broadway, New York; per year, $5; single copy, 10 cents.

Street Railway Journal (St. Ry. Journ.), monthly, 113 Liberty street, New York, per year, $2.

The Electrical Engineer (Elec. Engr.), monthly, 11 Wall street, New York; per year, $3; single copy, 30 cents.

The Electrical World (Elec. World), weekly, 177 Times Building, New York; per year, $3; single copy, 10 cents.

The Engineer (Lond. Engineer), weekly, London, England; per year, $10; single copy, 25 cents.

The Railway Master Mechanic (Mast. Mech.), monthly, "The Rookery," Chicago, Ill.; per year, $1; single copy, 10 cents.

The Mechanical World (Mech. World), weekly, Manchester, England; per year, 8s. 8d.; single copy, 1 penny.

The Street Railway Gazette (St. Ry. Gaz.), monthly, 8 Lakeside Building, Chicago; per year, $2; single copy, 25 cents.

Transactions American Society of Civil Engineers (Trans. A. S. C. E.), 127 East Twenty-third street, New York; per year, $10.

Arch *of Brick and Masonry.* A very good paper of 28 pp. By A. Wharton Metcalfe. Gives new tables for computing the form of arch suitable for any fixed load. Illustrated. *Trans. Liverpool Eng. Soc.*, Vol. VII., p. 19 (1886).

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Asphalt *and its uses.* By F. V. Greene, New York City. General descriptions, where found, chemical composition, methods of using, durability, etc. Illustrated, pp. 19. *Proc. A. I. M. E.*, Buffalo meeting, 1888.

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Average Haul. See Overhaul.

Axles. *Effects of Temperature on Railway Axles.* See Temperature.

—— *for 60,000-lb. Cars.* A paper read before the Western Railway Club by Mr. G W. Rhodes. *R. R. Gaz* , Feb 22, 1889; *Mast. Mech.*, March, 1889.

Back Water, *caused by Bridge Piers* and other obstructions. A theoretical investigation and some comparisons with actual tests, by S. W. Frescolm. *Jour. Eng. Soc. Lehigh University.*, Feb. 1889.

Ballast, *Burnt Clay for.* See Railroad Ballast.

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